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# Productivity of R&D institution: The case of Indonesia

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ABSTRACT

This study analyzes the performance of Indonesian R&D institutions based on R&D productivity. By applying an institutional approach, the effects of collective determinants such as quality of researcher, R&D budgets, locations and ages of R&D institutions on productivity are considered. Our findings show that these performance variables had strong and significant effects on R&D productivity. A national innovation system should be developed in developing countries with different models from those used in developed countries. The non-economic dimension is essential in developing national innovation systems in developing countries such as Indonesia.



## 1. Introduction

Empirical studies that analyze the productivity of R&D institutions, including their strengths and other factors, are limited for developing countries. This paper addresses the productivity of R&D institutions in Indonesia as an example of developing country, based on an institutional approach [14,5,30,38]. The study also analyzes these institutions' important collective determinants. In this case, we introduce technological and disseminating productivity in addition to scientific (publication) productivity. In terms of disseminating productivity, this indicator measures the capacity of R&D institutions to develop new technology that can be applied to society, whether for commercial or non-commercial use. That is, this indicator can measure the relevance of R&D activities to the social and economic contexts of the society. From this point of view, disseminating productivity is a more comprehensive indicator of the performance of R&D institutions.

A previous study compared and analyzed the performance of Indonesian R&D institutions based on scientific as well as technological productivity [35]. The effects of the type of R&D institution and their funding sources on productivity were considered. Based on their funding sources, the previous results showed that the R&D institutions with self-sufficient funding had better performance than did government-funded institutions. In accordance with their mandates, the state-owned enterprise R&D institutions were the most productive R, followed by ministerial R&D agencies and non-ministerial government research institutes, especially based on technological productivity.

This study built on the findings of the previous research mentioned above. Based on an institutional approach rather than the individual performances of researchers, this study focused on the effects of certain collective determinants on R&D productivity, such as researcher quality, R&D budget, location and age of institution, that were excluded from the previous study. More detailed analysis of the collective factors that contribute to innovation and research success in Indonesia was conducted based on MLG (multiple linear regression) statistical analysis.

This paper aims to contribute to the empirical evidence for the effects of the above determinants to the R&D productivity in developing countries such as Indonesia. The policy recommendations that are formulated in this paper are a next-step objective for improving the performance of R&D institutions in Indonesia.

## 2. R&D productivity

### 2.1. Institutional approach

The scientific productivity of researchers, which is used to measure the performance of scientific institutions, has been studied by many authors. The important determinants have been discussed, such as age, gender, type of position occupied by scholars, scientific discipline, training, average ages and positions of

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colleagues, the quality of institutions and colleagues, non-permanent researchers, size of institutions, funding, scientific collaboration, etc. [2,3,10,11,9,7,46].

However, there are two important notes, from our perspective, that should be discussed related to the debate on performance indicators for R&D institutions, especially in developing countries. First, the determinants and methodological approach that were adopted in the above productivity studies are more individually oriented. Indeed, the performance of R&D institutions can be evaluated by researcher productivity individually, but this approach is just one option.

Another option is a methodological approach based on the institution rather than the personal performance of the researchers, in which the performance of the R&D institution is evaluated based on institutional output or outcome indicators such as: efficiency, productivity, relevance, etc. A number of researchers had applied the institutional approach at the laboratory level in this field [9–11], as well as at the institutional level [2,4]. Some scholars suggest that further investigation of academic research production should take into account regarding the collective levels of organizations, such as in the institutional European context and at the laboratory level [17,42]. The results at a collective level may be quite different from the results for individual researchers, especially due to important externalities among researchers within labs, such as critical knowledge spillovers, reputation, sharing of equipment and facilities, complementarities between different types of researchers, or even different research agendas [10].

Second, scientific publications can measure the performance of R&D institutions—especially HEIs (higher education institutions)—that are weighted in basic research to provide proof of concept. However, for institutions that conduct applied research as well as experimental development on the downstream side, indicators such as patents, new technology, technical recommendations, and newly adopted technology are more favorable indicators. On the other side, international publications in developing countries still suffer from some constraints. For example, topics in international journals are less focused than are those in the developed world; there is limited access to researchers from developing countries for international journals; different languages and cultures, etc. [7]. Although bibliometric techniques result in generally valid and reliable estimates of productivity, they prove inadequate in studying scientific activity in developing countries because the scientific outputs of the developing world are not well represented in international scientific databases, reflecting differences in priorities in terms of local needs and global thematic interests [46]. On the one hand, the focus on scientific papers of analyzing research productivity is narrow. The essence of a researcher in a public research organization is not necessarily to publish papers per se but to produce and communicate knowledge through different mechanisms. Ref. [21] show that researchers in the agricultural sector produce three main types of outputs: 22.9% produce only papers, 23.7% only new recommendations and techniques, and 65.6% produce more than one output, of whom, 53.4% produce papers and other outputs. Hence, an analysis of papers does not allow for a broader measure of research productivity [21].

### 2.2. The collective determinants

The main studies by various authors on the collective determinants of R&D productivity are presented in Table 1. According to this table, an important collective factor that affects productivity in R&D institution is, first, the size of the institution. Ref. [4] found that size of the institution was never positively correlated with productivity. In nearly all fields, the most productive labs are the small ones, and the least productive ones may be large; in general, there is no positive relationship between size and productivity. Although the most productive institutes are likely to be found in smaller classes, the least productive are spread across classes of all sizes. Interestingly, the distributions of cost per publication and cost per international publication are again highly skewed. It is interesting to check whether the highly productive institutes are also those that spend more per publication. Clearly, if such a relationship held, a possible explanation for higher productivity would not lie in organizational factors or in the quality of the scientific environment but rather in greater access to funds, complementary personnel, or external resources. This study will check this relationship and demonstrate that determinants of R&D productivity mainly do not lie in greater access to funds, complementary personnel, or external resources but rather in organizational factors or in the quality of the scientific environment.

[9] and [3] revealed similar results. In a sample of Spanish manufacturing firms, the effects of firm size on R&D productivity were studied. Individual researchers publish more in small labs, which seems to indicate that the size of the institution plays an important role in both the individual and collective performance of researchers. This could be explained by standard advantages linked to smaller size: lower coordination costs, quicker decision processes, lower administrative burden, etc. [9].

Another collective determinant is R&D funding. Ref. [15] showed that laboratory funding structure was strongly correlated with the nature of research and concluded that research productivity was influenced by this structure. Ref. [7] studied the impact of the S&T budget on R&D productivity. They believed that budget had an impact on overall productivity with a lag, although it was difficult to determine the duration of the lag. A similar result was obtained by Ref. [16]; who analyzed the standing of Italian science and its evolution over the last three decades compared with the main scientific producers in Europe and found that, in Italy, both the scientific production and its quality were highly correlated with government R&D expenditures and higher education sectors. They showed that even though the level of funding had been dramatically low during the past decades compared with most EU science producers, science in Italy was able to increase its performance through 2007. The funding source model is one important policy instrument. The direct funding of R&D is one of the main policy instruments used by governments to support science and innovation in their priority areas. As noted in the OECD innovation strategy, countries are restructuring and adapting their research financing mechanisms, for example, by creating new agencies that are responsible for allocating resources, making greater use of competitively awarded project funding than institutional funding, exploring how to tie funding more closely to specific objectives and missions, and increasing the focus on the quality and relevance of institutions' research activities in pursuit of excellence and economic and social impact [41]. Ref. [9] obtained similar results. They showed that public contractual funding has positive impacts on the scientific publication intensity at the laboratory level.

Management and leadership in scientific institutions are also important collective determinants. Ref. [40] studied the internal governance in German universities and found a positive effect of strong central leadership, operational flexibility, goal agreements, and an internal evaluation system. Ref. [18] followed up the recent interesting research from other sectors and showed that the leader (the CEO) matters significantly for organizational performance. He demonstrated that a university president who himself was an accomplished scholar had a significant positive effect on his university's overall research performance. Ref. [1] empirically examined the effect of management on academic research productivity in Australian universities. The results suggested that management practices indeed appeared to have some positive effects on research

**Table 1**
Main studies on the collective determinants of scientific productivity.

| Determinant | Author | Main findings |
|---|---|---|
| Age | [2] | Age of institute is negatively correlated to productivity. |
| Reputation | [13] | Researchers at prestigious university departemens are more productive and more often cited. |
| | [20] | The quality of the universities is the critical variable for explaining future production. |
| Size | [4] | Size of institute is negatively correlated to productivity. |
| | [4] | Size of team indicated positively correlated to sceintific productivity. |
| | [9] | Laboratory size affects negatively the publication performance. |
| Agglomeration | [4] | No evidence that institutes have benefit from a strong agglomeration effect on productivity. |
| Funding | [15] | The reserach outcomes is strongly influenced by the funding structure. |
| | [9] | Public contractual funding plays positevly on the publication intensity. |
| | [7] | The budget has an impact on overall productivity with a lag. |
| | Defazio et al. (2009) | Impact of funding on productivity is generally positive. |
| | [16] | The scientific production and its quality were highly correlated with R&D expenditures. |
| | [41] | The competitive fund have greater effect on productivity than that of institutional fund. |
| Researcher | [2] | Average age of researcher in the institute is negatively correlated to productivity. |
| | [9] | Non-permanent researcher (foreign post-docs) enhance publication scores significantly. |
| | [9] | The intensity publication of colleagues infleunces positvely the researcher own production. |
| Management | [40] | A strong central leadership has a positive effect on the internal governance in German universities. |
| | [18] | A university president who himself is an accomplished scholar has a significant positive effect on overall research performance of the university. |
| | [1] | Management practices to have some positive effect on research productivity. |
| Collaboration | Defazio et al. (2009) | The presence of research funding might influence collaborative behavior. The overall impact of collaboration within the funded networks is weak. |
| | [46] | R&D productivity is significantly linked to professional network factors, but there is no evidence of any association with scientific collaboration. |
| | [24] | In the case of developing countries, the international collaboration had no significant effect on R&D productivity. |

productivity and that the effect was consistent over a considerable period of time. Universities with more intensive management approaches not only have higher absolute levels of research productivity, they also demonstrate also faster growth in productivity.

The next important determinant is the quality of the researcher. Ref. [9] showed that non-permanent researchers, especially post-docs, as well as the positions of colleagues, significantly enhance publication scores at the laboratory level. They indicated that the quality of the researchers and their status were important collective determinants for enhancing performance of scientific institutions. However, more evidence on the effects of researcher quality on scientific productivity is not available in the literature, especially for developing countries. This paper considers the relationship between researcher quality and the performance of R&D institutions.

The effects of age and location of R&D institutions on their performance were studied by Refs. [2,4]. They showed that age of the institution was negatively correlated with productivity. The sizes of institutions were correlated with their ages in an almost linear relationship. Large institutions are generally also older; no large institutions (more than 25 researchers) are younger than 25–30 years. The large majority of these institutions grew at a rate of less than one researcher per year and less than two employees per year over their lifetimes. This means that institutions grow in size linearly (in absolute differences) over time with this rule of thumb. Accelerated growth is also visible for a few institutions. Ref. [2] found that the few institutions that grew more rapidly (more than one researcher and two employees per year of life span) were predominantly old and were growing as they matured. Only a few small and young institutes grew at an accelerated rate. This means that rapid growth is not achievable in an institution's early stage of life but rather during the later stages.

Related to the effects of R&D institutions' locations [4], tested the effects of agglomeration on research productivity. By introducing the AGI (geographical agglomeration index) to measure the number of institutions in the same city, they concluded that there were significant effects of the agglomeration of institutions in the same city on research productivity. Indeed, agglomeration is a meaningful aspect of mobilizing resources as well as a support system for research organizations. However [4], found no evidence that institutions had benefited from a strong agglomeration effect on productivity. In contrast [45], found some evidence that the effects of an institution on its research intensity varied in different economies. To enhance the above results, this study discusses the effects of R&D institutions' ages and locations on their productivity in Indonesia. It will be verified that R&D institutions on Java Island, a more economically advanced island, are more productive than are those that are located elsewhere in Indonesia.

## 3. R&D institutions in Indonesia

R&D Institutions in Indonesia are classified into five types [24,35]: (1) universities (HEIs), which have the main responsibility for improving the quality of human resources through formal education, as well as being responsible for developing S-T mainly through basic research; (2) public R&D institutions, which are funded by the government but not affiliated directly with any ministry, known as non-ministerial government research institutions (PRI-NM); these mainly develop frontier and cross-cutting research; (3) R&D agencies within a ministry, known as ministerial research and development agencies (PRI-M), with a clear mandate to provide knowledge and technology as required by the ministry in formulating public policies and to provide technical or technological assessments as well as to develop applied, adaptive and innovation research; (4) R&D units within industrial or business firms that have the responsibility of developing process and product technology; and(5) R&D agencies formed as state-owned enterprises (R&D-SO), which are especially focused on plantation products such as crude palm oil, coffee, cocoa, rubber, sugar, etc. In addition to PRI-M for R&D agencies within a central government ministry, R&D agencies within a regional government, known as regional R&D agencies, are also present. However, this study is limited to HEI, PRI-NM and PRI-M (called PRI in this paper), and R&D-SO because there is a very limited number of non-government R&D institutions in Indonesia and there is limited access to R&D units in industry.

**Table 2**
The science system in Indonesia: A centralized archetype.

| No. | Parameter | Indonesian case |
|---|---|---|
| 1 | Ministerial structure | Single ministry (MoRT) |
| 2 | Priority setting | Primarily top-down, stakeholder involvment only at advisory body level (DRN) |
| 3 | Funding streams | Primary institutional funding<br>Direct funding for PRI<br>Competitive funding beside of direct funding in HEI<br>Relatively few competitive funding<br>No funding from research council (DRN). |
| 4 | Role of research performers receiving public support (PRI and HEI) | Research mainly in PRI<br>HEI come second |
| 5 | Evaluation | No periodic committee evaluation of plans and peformance of research institutions |
| 6 | Primary strength | Stable career of researcher, continue funding streams, long-term high-risk research |
| 7 | Primary drawbacks | Slow to respond challenges<br>Hard to motive or remove less productice researcher<br>Separation of research and training<br>More hierarchical, bureacratic, longer for career independence<br>Subject to change in government<br>One year basis and rigidity of R&D budget<br>Public Private Partnership (PPP) needs government action |

Based on the science system archetypes that were developed by OECD [36], both the structure and the governance of Indonesia's science system could be categorized as a centralized archetype. The primary characteristic of this archetype is presented in Table 2. Based on the ministerial structure aspect, the single and centralized ministry that has the responsibility for developing R&D in Indonesia is MoRT. This is different from countries that are formed by dual-system or decentralized archetypes, in which responsibility for developing R&D is distributed through both federal and state or regional ministries or in multiple government departments. Indeed, the sectored ministries perform sectoral research to support policy formulation and implementation in their sectors, but the ministry that is responsible for developing R&D at the national level is the MoRT. Unfortunately, this centralistic structure is not automatically followed by “central power” in controlling and coordinating R&D development in Indonesia by the MoRT, especially in planning and controlling. This is caused by the mechanisms R&D budget planning as well as program controlling, which are not managed through “one gate” under the MoRT. On the other side, the coordination instruments are too weak for this purpose. From 310 units of R&D in PRI, only 84 units (less than 30% of the total number of R&D institutions) are PRI-NM, under the coordination of MoRT. The remaining 226 units (more than 70% of the total number of R&D institutions) are PRI-M, under the management of sectorial ministries. The HEIs are coordinated by the MoEC.

HEIs, in the Indonesian science system, are mainly public universities with 687 R&D units [32,33]. There are as many as 297 R&D units from medium and large factories that actively conduct R&D[1] [26].

The above R&D units are distributed nationally throughout the main islands of Indonesia, with 70% located on Java Island. The others, 11%, 7%, 6%, 4% and 3%, respectively, are distributed in Sumatera, Sulawesi, Kalimantan, Bali-Nusatenggara, and Maluku-Papua Islands [31]. These profiles can be easily understood due to the more advance economy of Java Island compared with those of the other islands (Java Island contributed 57.8% of the national GDP in 2013) and its higher density of inhabitants as well as its wider availability of energy, IT, infrastructure, etc. This study will discuss the effects of the locations of R&D institutions on their productivity. The results will verify whether the R&D institutions on Java Island are more productive than those that are located elsewhere.

Based on the age distribution, it is known that the oldest R&D institutions in Indonesia are the R&D-SOs, which are more than 100 years old. These institutions were established during the colonial era under the coordination of the national plantation association. Before being designated state-owned companies in 2008, the R&D-SOs were coordinated under the MoA. In contrast, other R&D institutions were established gradually after the independence of the Republic of Indonesia in 1945. This study will also discuss the effects of age of the institution on R&D productivity.

In terms of setting priorities, the research agendas in Indonesia are decided as top down, based on the 2005–2030 National Long-Term Development Plan (specifically, the 25-year plan according to Act no. 17/2007 and coordinated by the MoDP) and the 2015–2019 national strategic policy on science and technology as well as the National Research Agenda (the 5-year plan under an MoRT decree). Stakeholders were involved through public hearings such as a national coordination meeting on science and technology that was substantially coordinated by the DRN. According to Act no. 18/2002 on the National System of Science and Technology, the DRN has the responsibility to support the MoRT to formulate the ARN.

In terms of funding streams, R&D budgets in Indonesia are mainly institutionally funded and non-competitive. A small amount of competitive funding is coordinated by the MoRT, a budget of 100 billion IDR (1% of the total government S-T budget of 10 trillion IDR). The remaining 99% of the total government S-T budget in Indonesia is direct funding to R&D institutions. In HEIs, in addition to direct institutional funding, there is also a small amount of competitive funding coordinated by the MoEC. The DRN provides no research funding, and there are no PRIs dedicated to managing funding, planning, or evaluating any R&D infrastructures. The central R&D budget planning is executed by the MoDP and the MF, based on proposals by the MoRT, sectorial ministries and the head PRI-NM, respectively. The systems and mechanisms of R&D budget planning and program control are not managed entirely by the MoRT.

The main R&D actors in Indonesia are PRIs (42% of the budget). The R&D budget for HEIs, PRI-NMs, PRI-Ms and industry are 38.5%, 9%, 33% and 18.7%, respectively, of the total R&D budget of 0.08% of the GDP [26] and [31]. According to Act No. 12/2012 on Higher Education [34], the government must promote R&D activities at private and public universities. Based on this provision, R&D budgets for HEIs will increase significantly. At least 30% of HEIs'

[1] Of 23.000 medium-sized and large factories that were surveyed, 1.228 factories owned their own R&D units. Two hundred ninety-seven R&D units, 1.29%, were part of factories that conducted their own R&D [26].

operational support budgets should be allocated to R&D.

Based on the budget amounts presented above, the R&D investment by industry still shows lower performance compared with the government's investments. The R&D budget by industry is 18.7% of the total R&D budget and mainly consists of in-house activities. The percentage of the extramural R&D budget from industry that is allocated to HEIs is 7% [26], in an inverse relationship with R&D budgets in average OECD countries, where 70% of total R&D is funded by industry. Ten percent of these R&D budgets are allocated extramurally in HEIs and PRIs [37].

As shown in Fig. 1, HEIs mainly perform basic research, and applied research to a lesser extent. PRI-NMs mainly perform strategic and applied research, and PRI-Ms perform adaptive research and development to support sectoral policy formulation and implementation [35]. According to national data from 2011 [32] and [26], the budget allocations for basic research, applied research and experimental development are 17.5%, 56.0% and 26.5%, respectively. This is different from advanced countries, where HEIs have significant roles in applied research due to the extramural R&D budgets of different industries from research contracts or collaboration. In Indonesia, the role of HEIs in applied research is of lower stature than that of PRIs due to low industry investment in research. Consequently, applied research in Indonesia is mainly performed by PRIs.

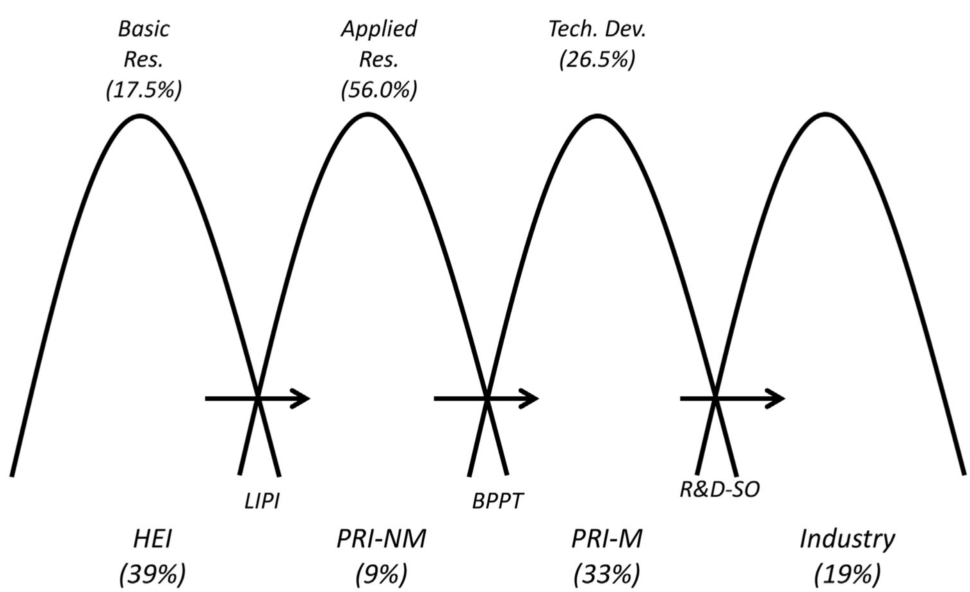
Based on the researcher composition in Indonesia, HEIs are the institutions where most researchers are located. This profile matches with the distribution of R&D institutions and R&D budgets. The proportions of researchers in HEIs, PRI-NMs, PRI-Ms and industry based on FTE (full-time employees) are 54%, 11%, 16% and 19%, respectively [31] and [26].

The R&D institutions in Indonesia, as in other developing countries [7,12,46], generally have many problems and externalities. Public research institutions are managed as "business-as-usual" public institutions in general, with no attention to special qualifications as research institutions with distinctive requirements. Under current government budgeting mechanisms, the public research institutions have no strong motivation to cooperate with outsiders to support technology development in industry. The linkage between R&D institutions on the supply side with industry in the demand side is generally weak. Rapid changes in industrial technology development are difficult for R&D institutions to follow due to their limited human resources. The operation system for public research institutions does not offer much opportunity to build linkages with the private sector. Incentive systems that support these linkages are weak; there is no national industrial policy related to government procurement to support domestic industry [43] and [25,44]. Indonesia's vice president, Budiono, criticized how science and technology in Indonesia are not yet optimally utilized for national development, how R&D output was limited to scientific publications and prototypes, and how national S-T development planning was weak [8]. Moreover, there are often overlaps the implementation of research activities and the low level of synergy between R & D institutions.

## 4. Analytical framework and data sources

### 4.1. Analytical framework

To measure R&D productivity, this paper suggests three types of measures as proxies, namely: 1. publication productivity, based on scientific papers published in international scientific journals; 2. technological productivity, based on new technological products or services offered by the R&D institution; and 3. disseminating productivity based on technological products or services applied socially or economically to the public by the R&D institution. Ref. [21] broadly defined research productivity as papers, new recommendations, and new techniques in agriculture-related fields to investigate academy—farmer interactions and their effects on R&D




| | | | | |
|---|---|---|---|---|
| Researcher | 54% | 11% | 16% | 19% |
| R&D Unit | 683 | 84 | 226 | 297 |

Note: ( ) R&D budget

**Fig. 1.** The linear model of innovation process in Indonesia: role of each R&D institutions modified from Ref. [35].

productivity. In developing countries, many problems and externalities restrict researchers from producing material for international scientific publications, such as different themes and focuses from those in developed countries, language barriers, access to journals, etc. [21]. The limits of this proxy for measuring R&D productivity were discussed by Ref. [3].

Scientific productivity (sciPROD, #/res/year), technological productivity (techPROD, #/res/ten years), and disseminating productivity (desPROD, #/res/ten years) are defined by eqs. (1)–(3).

$$\text{sciPROD} = \textit{scientific publications/researcher/year} \quad (1)$$

$$\text{techPROD} = \textit{technological products(services)} \times \textit{/researcher/ten years} \quad (2)$$

$$\text{desPROD} = \textit{technological products applied/researcher/ten years} \quad (3)$$

This study will discuss the effect of researcher quality and R&D budget on R&D productivity. Statistical analysis of MLGs (multiple linear regressions) is applied to analyze the causality of the variables. We assumed that there would be no bidirectional relationship (non-recursive) between the dependent variables and the predictors, and thus that we could avoid the endogeneity problem [22,45]. Additionally, the OLS method could be applied to estimate the regression equation expressed as eq. (4).

$$P_i = \beta_0 + \beta_i X_i + Z_i \delta + \varepsilon_i \quad (4)$$

where $P_i$ is R&D productivity for each institution observed of i; $X_i$ are predictors of researcher quality and R&D budget for i; $Z = (z_1, z_2, z_3 \ldots z_k)$ the vector of the control variables; and $\varepsilon_i$ is the error term that is assumed to be normally and independently distributed. Then, βo and βi are the intercept and regression coefficients, respectively. βi captures the effect of the average predictors on research productivity, whereas $\delta = (\delta_1, \delta_2, \delta_3, \ldots \delta_k)$ is the parameter vector for the control variables. There are a total of k+2 parameters to estimates, and the parameters of interest are the regression coefficient (βi), level of significance (σ), and determination coefficient ($R^2$), respectively. The variables in this study and short descriptions of them are presented in Table 3. Equation (4) was estimated using the OLS estimator in SPSS version 21 [28].

To establish that the linear assumption was applied in the regression equation, a number of tests were conducted such as the Kolmogorov–Smirnov normality test of data distribution; the multicollinearity test with tolerance value of >0.1 and VIF <10, to verify that two or more independent variables correlated perfectly; the heteroskedacity test using scatter plots, to avoid inefficiency of estimators that would result in very high $R^2$ values and; the residue auto correlation test using the Durbin–Watson method.

The variable for researcher quality was defined as the proportion of senior researchers to total researchers at the institute level (senRES), and the alternate variable was the percentage of researchers who held a PhD degree (PHD). R&D budget was measured with RDEX, and the alternate variable was the percentage of the R&D budget paid by the government (RDEXgov). The variable for productivity was scientific productivity (sciPROD), and the alternate variables were technological productivity (techPROD) and disseminating productivity (desPROD). The core variables in this study were scientific productivity (sciPROD), percentage of senior researchers (senRES), and R&D budget (RDEX).

The control variables in the above linear regression were the number of institution staff members (STAFF); number of researcher in the entire institution (RES); and institution expenditures (EX). This study also used dummy variables for controls, such as: type of R&D institution (TYPE), where “1” is HEIs, “2” is PRIs, and “3” is R&D-SOs; age of institution (AGE), where “1” is for age older than > 15 years and “0” is for age less than < 15 years; and institution's location, whether on Java Island or elsewhere (JAVA), where “1” is for location on Java Island and “0” is for institutions located elsewhere in the country.

To determine the strength of the effect of researcher quality and R&D budget on productivity, a number of tests were conducted such as:

(1) Using control variables in the regression model and applying a stepwise method as well as an enter method [28].
(2) Using alternate dependent variables for scientific productivity (sciPROD) with technological (techPROD) and disseminating (desPROD) productivity.
(3) Switching the senRES and RDEX predictors with their alternates, PHD and RDEXgov.
(4) Varying the calculations by removing the TYPE, AGE and JAVA control variables and then splitting the input data before the regression based on categories such as: a. institution location (JAVA); b. type of R&D institution (TYPE): HEI or non-HEI; c. age of institution (AGE): <15 years or > 15 years. This splitting technique was used to observe the effects of JAVA, TYPE, and AGE by avoiding their direct effects as control variables [22]. The weak point of this technique is the reduced sample size.

**Table 3**
Main variables.

| Variable | Unit | Short description |
|---|---|---|
| **Dependent** | | |
| Scientific Productivity (sciPROD)[a] | Paper/researcher | Number of scientific paper produced by each researcher a year (average value for the year 2011–2013). |
| Tech. Productivity (techPROD) | Tech/researcher | Number of technology produced by each researcher for ten years (2003–2013). |
| Desseminating Productivity (desPROD) | Tech/researcher | Number of technology applied/commercialized to public by each researcher for ten years (2003–2013). |
| **Independent** | | |
| Percentage of senior researcher (senRES)[a] | (%) | Percentage of senior researcher. |
| Percentage of PhD holder (PHD) | (%) | Percentage of Ph.D holder to total researcher. |
| R&D expenditure (RDEX)[a] | Billion IDR | R&D expenditure (averaged value for the year 2011–2013). |
| R&D Budget support by gov (RDEXgov) | (%) | Percentage of R&D Budget support by government (averaged value for the year 2011–2013). |
| Number of staff (STAFF) | Man | Number of staff in 2013 |
| Number of researcher (RES) | Man | Number of researcher in 2013 year |
| Institutional expenditure (EX) | Billion IDR | Institutional expenditure (averaged value for the year 2011–2013). |
| Type of institution (TYPE) | – | Type of institution such as: PRI (1), University (2), R&D-SO (3). |
| Located at Jawa (JAVA) | – | Located at Java Island (1) or outside Java Island (0). |
| Institution's age (AGE) | – | Institution age more than 15 years (1) or less than 15 years (0) |

[a] Core variables.

### 4.2. Data source

Surveys on the performance of PRIs and HJEIs in Indonesia were administered separately in 2011 and 2012 by the MoRT [31] and [33]. Of the total number of existing PRIs, data were obtained on 250 R&D units (81% of the population). Based on a preliminary study, 52 R&D units saw high performance in R&D productivity (including HEIs and R&D-SOs). Based on the above number, 16 R&D units were selected beginning in 2012, when the centers of excellence were supervised by the MoRT. Under this program, the MoRT provided incentives to improve institutions, develop their human resources, improve their networking, etc. These centers of excellence were distributed geographically throughout the six main islands of Indonesia, including their R&D focuses. A survey on research productivity for the above high-performance R&D units was conducted in March 2014 to evaluate their performance.

Based on the purpose of this study, the three dependent variables related to R&D productivity were: scientific productivity (sciPROD), technological productivity (techPROD), and disseminating productivity (desPROD), as defined by equations (1)–(3). In this study, scientific publication is measured by number of scientific papers published in international or accredited domestic journals annually averaged over the last three years. Annual averaging for three years was conducted to reduce measurement bias as well as to accommodate the lagged nature of research output. The measure of "new technology" relating to technological productivity is defined as the number of new technologies produced by an R&D unit in the last ten years. Similarly, the measure of "applied new technology" relating to disseminating productivity is defined as the number of new technologies that were applied or commercialized by an R&D unit in last ten years. This ten-year basis was used because the data on new technology produced or applied to society within one year were very limited.

On the other side, related to the independent variables used in this study, the measure of "senior researchers" is defined as the number of qualified researchers (calculated by FTE) based on track records as well as their experiences; this variable is classified by institution. This variable is generally assumed to be the equivalent of the "senior researcher" in the researcher classifications regulated by the MoRT through the LIPI. The R&D budget defined is this study is the R&D budget allocated by each R&D unit annually averaged over the last three years. Brief descriptions of the variables used in this study are presented in Table 3. The statistical summary of the study is presented in Table 4.

One limitation of the data in this study is the relatively small number of observations compared with the total population of PRI R&D units, which is 310. However, we believe that the selected R&D units that were observed in this study were among the best performers based on their productivity, not only scientific but also technological and disseminating productivity, in terms of their relevance to society. From this perspective, the study reflects the upper bound of PRI performance in Indonesia rather than the average.

**Table 4**
Summary statistics for cross-institution data.

| Variable | Minimum | Maximum | Mean | Std. Deviation |
|---|---|---|---|---|
| SciPROD[a] | 0.03 | 0.50 | 0.163 | 0.114 |
| TechPROD | 0.02 | 1.60 | 0.457 | 0.495 |
| DesPROD | 0.00 | 1.29 | 0.259 | 0.359 |
| SenRES[a] | 3 | 86 | 42.88 | 26.57 |
| PHD | 3 | 87 | 33.69 | 25.34 |
| RDEX[a] | 0.80 | 23.80 | 7.929 | 6.609 |
| RDEXgov | 0 | 100 | 53.31 | 37.76 |
| STAFF | 9 | 1031 | 226.88 | 255.20 |
| RES | 7 | 166 | 84.19 | 49.50 |
| EX | 1.10 | 224.50 | 54.21 | 70.42 |
| TYPE | 1 | 3 | 2.13 | 0.50 |
| JAVA | 0 | 1 | 0.50 | 0.516 |
| AGE | 1 | 102 | 23.88 | 31.99 |

[a] Core variables.

## 5. Results and analysis

### 5.1. Preliminary analysis

Table 5 shows the correlations between the variables discussed in this study, with special attention to the correlations between the measures of researcher quality (senRES and PHD) and R&D budget (RDEX and RDEXgov) and measures of R&D productivity. PHD and senRES correlated positively with each R&D productivity measure. However, R&D budget (RDEX and RDEXgov) correlated negatively with each R&D productivity measure. The strongest correlation was for the relationship between researcher quality and sciPROD, as opposed to techPROD and desPROD. The correlation between R&D budget and R&D productivity also shows a similar result, a stronger correlation between R&D budget with sciPROD than with techPROD or desPROD.

An interesting finding was a significant and positive correlation between techPROD and desPROD. In contrast, there was no significant correlation between sciPROD and techPROD or desPROD. This result shows that scientific productivity was not correlated significantly with technological or disseminating productivity but that technological productivity was correlated significantly with disseminating productivity. This result occurs because the technology dissemination throughout and feedback from society stimulate researchers to pursue new technologies. Ref. [21] found a similar result, that there was a positive and significant correlation between the two outputs, although in their study, the comparison was between new techniques and recommendations in agricultural research. This was caused by the feedback and recommendations to farmers, which stimulated researchers to develop more new techniques.

Simple linear regression (SLR) is used to correlate two variables, and in this study, it was used correlate one dependent variable with one independent variable based on equation (5). According to that equation, there were 12 sets of separate simple regression models for all observations, including 3 measures of R&D productivity: sciPROD, techPROD and desPROD; two measures of researcher quality (senRES and PHD); and two measures of R&D budget (RDEX and RDEXgov). The results showed that the effects of researcher quality (senRES and PHD) and R&D budget (RDEX) on scientific productivity (sciPROD) were significant at the level of $p < 0.05$. The regression coefficients ($\beta$), which reflect the strength of the independent variables on the dependent variable, were 0.670, 0.525 and −0.586, respectively, for senRES, PHD and RDEX. However, the effect of RDEXgov on scientific productivity (sciPROD) was not statistically significant. This SLR model could explain the effects of the independent variables on R&D productivity, which is solely indicated by the determination coefficient $R^2$, which was 0.449, 0.276, and 0.243 for senRES, PHD and RDEX, respectively.

In contrast, the general effects of researcher quality (senRES and PHD) and R&D budget (RDEX and RDEXgov) on the productivity measures techPROD and desPROD were not significant, as indicated by their very low $R^2$ values, (both $< 0.050$). This result is consistent with the results presented in Table 5.

$$P_i = \beta_0 + \beta_i X_i + \varepsilon_i \tag{5}$$

According to the above preliminary analysis, it can be deduced that the effects of researcher quality and R&D budget on research

**Table 5**
Matrix correlation.

| | SciPROD | TechPROD | DesPROD | SenRES | PHD | RDEX | RDEXgov | STAFF | RES | EX | TYPE | JAVA | AGE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SciPROD | 1 | | | | | | | | | | | | |
| TechPROD | 0.020 | 1 | | | | | | | | | | | |
| DesPROD | 0.043 | 0.932** | 1 | | | | | | | | | | |
| SenRES | 0.670** | 0.066 | −0.057 | 1 | | | | | | | | | |
| PHD | 0.525** | 0.045 | 0.016 | 0.529** | 1 | | | | | | | | |
| RDEX | −0.586** | −0.206 | −0.272 | −0.332 | −0.325 | 1 | | | | | | | |
| RDEXgov | 0.122 | −0.123 | −0.065 | 0.377 | 0.116 | 0.133 | 1 | | | | | | |
| STAFF | −0.398 | 0.231 | 0.145 | −0.446** | −0.508** | 0.358 | −0.372 | 1 | | | | | |
| RES | −0.304 | −0.411 | −0.498** | 0.050 | −0.369 | 0.607** | 0.082 | 0.113 | 1 | | | | |
| EX | −0.453** | 0.114 | 0.111 | −0.677** | −0.672** | 0.510** | −0.270 | 0.703** | 0.205 | 1 | | | |
| TYPE | −0.067 | 0.451** | 0.416 | −0.245 | −0.160 | 0.075 | −0.571** | 0.605** | −0.165 | 0.511** | 1 | | |
| JAVA | 0.121 | 0.578** | 0.552** | −0.073 | 0.033 | −0.369 | −0.094 | 0.088 | −0.416 | −0.174 | 0.000 | 1 | |
| AGE | −0.085 | 0.522** | 0.648** | −0.475** | −0.348 | 0.003 | −0.314 | 0.353 | −0.304 | 0.520** | 0.522** | 0.262 | 1 |

** significance at ($p < 0.05$).

productivity are strong and significant, especially for senRES, PHD and RDEX, which are used as predictors where sciPROD is used as the dependent variable. However, the above SLR model cannot explain the extent of the effects of the independent variables on the dependent variable simultaneously by introducing control variables. Consequently, it is important to develop a linear regression model whose variables are controlled based on equation (4) and then test its robustness.

### 5.2. Regression analysis

This study argues that researcher quality and R&D budget have strong influence on productivity in R&D institutions in Indonesia. The results of regression analysis using senRES and RDEX as independent variables and sciPROD as the dependent variable are presented in Table 6, column (1). Running in stepwise mode, the regression result shows that both researcher quality and R&D budget can simultaneously explain their influence on scientific productivity (sciPROD) with an $R^2$ value of 0.598 (nearly 60%) at the significance level of $p < 0.01$. This indicates that the contributions of the other variables remained below 0.312, nearly 30%. On the other side, individually, researcher quality and R&D budget strongly influenced research productivity, with regression coefficients ($\beta$) of 0.535 and −0.408, respectively, at $p < 0.05$ significance.

Based on the $\beta$ indicator above, it can be understood that researcher quality (senRES) positively affects research productivity (sciPROD) but that R&D budget (RDEX) has a negative effect. That is, a 1 point increase in the researcher quality measure will increase research productivity by 0.535 point under a constant value for R&D budget. Additionally, a 1 point increase in the R&D budget measure will decrease research productivity by 0.408 point, under a constant value for researcher quality.

To understand the effects of other variables, we controlled the above regression model with variables for number of staff members (STAFF), number of researchers (RES), institutional expenditures (EX), type of institution (TYPE), location of institution (JAVA), and institution age (AGE). The results are presented in columns (2) and (3) of Table 6. Even after being controlled with the other variables listed above, our calculation shows that researcher quality and R&D budget still had strong and significant effects on R&D productivity. This result shows that the above control variables had no significant effects on the model.

Calculating using enter mode, as an alternative to stepwise mode, showed different results, as presented in columns (4) and (5) of Table 6, and $R^2$ was increased. This indicates that all independent variables simultaneously had strong influence on the dependent variable. However, their level of significance ($p < 0.10$) was lower than that calculated by stepwise mode ($p < 0.01$). On the other side, individually, the effects of senRES and RDEX on sciPROD were weak and not significant. Based on this result, this study calculated the regression model in stepwise mode.

**Table 6**
Regression coefficient for dependent variable: Scientific productivity.

| Variable | Stepwise method | | | Enter method | |
|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) |
| senRES | 0.535** (0.013) | 0.535** (0.013) | 0.535** (0.013) | 0.671* (0.073) | 0.731 (0.161) |
| RDEX | −0.408** (0.047) | −0.408** (0.047) | −0.408** (0.047) | −0.446 (0.216) | −0.444 (0.350) |
| STAFF | – | −0.018 (0.935) | −0.018 (0.935) | −0.184 (0.553) | −0.166 (0.706) |
| RES | – | 0.148 (0.551) | 0.148 (0.551) | −0.041 (0.902) | 0.033 (0.943) |
| EX | – | 0.260 (0.341) | 0.260 (0.341) | 0.572 (0.171) | 0.588 (0.343) |
| TYPE | – | – | 0.101 (0.599) | – | −0.103 (0.821) |
| JAVA | – | – | 0.012 (0.955) | – | 0.080 (0.803) |
| AGE | – | – | 0.227 (0.282) | – | 0.172 (0.657) |
| F | 9.650 | 9.650 | 9.650 | 2.705 | 1.329 |
| (p value) | 0.003*** | 0.003*** | 0.003*** | 0.093* | 0.397 |
| $R^2$ | 0.598 | 0.598 | 0.598 | 0.703 | 0.727 |

Running with SPSS linier regression OLS by Stepwise method. (1) regression with independent variables of senRES and RDEX, (2) regression with predictor and controll variables, (3) regression with predictor, controll variables and determinants of scientific productivity, (4) regression by Enter method with predictor and controll variables, and (5) regression by Enter method with predictor, controll variables and determinants of scientific productivity. Parentheses are robust significance.
*** significance at ($p < 0.01$).
** significance at ($p < 0.05$).
* significance at ($p < 0.10$).

#### 5.2.1. Alternatives measures of R&D productivity

Robustness tests were performed to verify the strength of the regression model by replacing sciPROD with its alternatives, techPROD and desPROD, and keeping other measures constant. The results of this variation are presented in Table 7. Columns (2) and (3) of the table show the effects of senRES and RDEX as well as other control variables simultaneously with R&D productivity, which, as indicated by both the $R^2$ and the significance level, were relatively constant even when the dependent variable varied. However, individually, the effects of senRES and RDEX on techPROD and desPROD as indicated by regression coefficient β and level of significance σ were not statistically significant. The β values for senRES and RDEX decreased to half their value in the initial model with sciPROD, and similar results were obtained for level of significance. Their values decreased from $p < 0.05$ to $p > 0.10$.

Differences in the above results are caused by the effects of the control variables TYPE, JAVA, and AGE. The individual effects of these measures on R&D productivity, which maintained the strength of $R^2$ and level of significance are presented in columns (2) and (3) of Table 7. Consequently, in this model, even individually, senRES and RDEX had no influence on R&D productivity. However, all of the independent variables together with TYPE, JAVA, and AGE did have a significant effect on R&D productivity. The effects of TYPE, JAVA, and AGE will be discussed in depth in sub-chapter 5.3.

#### 5.2.2. Alternative of predictor variables

Other robustness tests were performed to verify the strength of the regression model by replacing the predictor variables senRES and RDEX with their as alternates, PHD and RDEXgov, while keeping other measures constant. The results are presented in column (2) of Table 8. According to these results, simultaneously, the effects of all independent variables on R&D productivity decreased, as indicated by the decreasing $R^2$ and significance levels, when the predictor variables were replaced. $R^2$ decreased from 0.598 to 0.276 because RDEXgov had no significant effect on R&D productivity. On the other side, PhD had a strong and significant effect on R&D productivity, with β and σ values of 0.525 and $p < 0.05$, respectively.

From this result, it can be concluded that researcher quality and R&D budget had strong and significant effects on R&D productivity.

Number of senior effect effects and PhD had strong, significant, and positive effects on R&D productivity. Ref. [1] obtained the similar finding that senior staff (equivalent to associate and full professors) and staff members with PhDs at Australian universities had significant and positive effects on research productivity. The effects of researcher quality, as indicated by senRES and PHD in this study, were different from that of researcher quantity. The last measure corresponds to size and had a negative effect on research productivity [4,9]. It is reasonable to expect that researcher quality would have a positive effect on research productivity given that researchers are the primary actors in research activities. Researcher quality is understood to be the main contributor to research productivity and performance. Consequently, increasing the numbers of professionals and experts in the research activities of an R&D institution will increase the organization's research productivity. According to the evidence obtained in this study, human resources management policies that enhance researcher quality through research collaborations, training, and education both domestic and international are important for increasing research productivity at R&D institutions.

This study's findings also showed that R&D budget had a negative, strong, and significant effect on research productivity in R&D institutions in developing countries such as Indonesia.

We can argue that R&D budgets reflect the sizes of R&D institutions. Previous studies revealed that size has a negative effect on productivity, that is, productivity is inversely proportional to R&D institution size [4,9]. These effects may be caused by the high solidarity and ease of internal coordination in small institutions. The administration and management burdens of small institutions are smaller than those for larger institutions. In addition, larger institutions consume more energy for their many support systems, which subsequently reduces organizational productivity. These results appear to indicate that the size of an institution plays an important role in the performance of R&D institutions. Ref. [9] argued that standard advantages were linked to smaller size: lower coordination costs, quicker decision-making processes, lower administrative burdens, etc. Smaller institutions, with smaller R&D budgets, have lower scientific and technological costs than do larger institutions. This indicates that the smaller institutions pay lower costs to publish one scientific paper or produce one new technology than do larger institutions. R&D institutions with smaller budgets are more efficient than are the larger ones.

Interestingly, the distributions of cost per publication are highly skewed [4]. We do not know the reason for this finding, and it would be of interest to study whether highly productive institutions are also those that spend more per publication. If this relationship held, then a possible explanation for higher productivity would not lie in organizational factors or in the quality

**Table 7**
Rubustness chek for alternative dependent variables of scientific productivity.

| Variable | (1) sciPROD | (2) techPROD | (3) desPROD |
|---|---|---|---|
| senRES | 0.535** (0.013) | 0.234 (0.245) | 0.297 (0.156) |
| RDEX | −0.408** (0.047) | −0.031 (0.887) | −0.143 (0.486) |
| STAFF | −0.018 (0.935) | −0.147 (0.558) | −0.092 (0.651) |
| RES | 0.148 (0.551) | −0.120 (0.591) | −0.207 (0.329) |
| EX | 0.260 (0.341) | −0.023 (0.924) | −0.158 (0.511) |
| TYPE | 0.101 (0.599) | 0.451** (0.032) | 0.190 (0.397) |
| JAVA | 0.012 (0.955) | 0.578*** (0.009) | 0.410** (0.047) |
| AGE | 0.227 (0.282) | 0.204(0.401) | 0.540** (0.013) |
| F | 9.650 | 7.563 | 8.833 |
| (p value) | 0.003*** | 0.007*** | 0.004*** |
| $R^2$ | 0.598 | 0.538 | 0.576 |

Running with SPSS linier regression OLS by Stepwise method. Parentheses are robust significance.
*** significance at ($p < 0.01$).
** significance at ($p < 0.05$).
* significance at ($p < 0.10$).

**Table 8**
Rubustness chek for alternative predictor variables.

| Variable | (1) | (2) |
|---|---|---|
| senRES | 0.535** (0.013) | – |
| RDEX | −0.408** (0.047) | – |
| PHD | – | 0.525** (0.037) |
| RDEXgov | – | 0.062 (0.797) |
| STAFF | −0.018 (0.935) | −0.177 (0.523) |
| RES | 0.148 (0.551) | −0.128 (0.621) |
| EX | 0.260 (0.341) | −0.183 (0.570) |
| TYPE | 0.101 (0.599) | 0.018 (0.942) |
| JAVA | 0.012 (0.955) | 0.106 (0.664) |
| AGE | 0.227 (0.282) | 0.111 (0.664) |
| F | 9.650 | 5.330 |
| (p value) | 0.003*** | 0.037** |
| $R^2$ | 0.598 | 0.276 |

Running with SPSS linier regression OLS by Stepwise method. Parentheses are robust significance. (1) Predictors are senRES and RDEX, (1) Predictors are PHD and RDEXgov.
*** significance at ($p < 0.01$).
** significance at ($p < 0.05$).
* significance at ($p < 0.10$).

of the scientific environment but rather in greater access to funds, complementary personnel, or external resources [4].

Figs. 2 and 3 attempt to answer the above problem. These figures show that the relationship between productivity and efficiency (number of papers or technologies per one billion IDR) is positive and linear with an $R^2$ value of 0.60. Pearson's correlation calculation for the two data sets are presented in Figs. 2 and 3, which show that the correlations between them are strong and significant at the 0.05 level; the Pearson correlation coefficients were 0.795 and 0.537, respectively, for scientific and technological productivity. This result means that the highly productive institutions are those that show highly efficient spending per publication. According to this relationship, the explanation for higher productivity primarily lies in organizational factors or in the quality of the scientific environment, not in greater access to funds, complementary personnel, or external resources.

According to this finding, it can be understood that size and quantity measures (for example, number of researchers, R&D budget, etc.) generally tend to have a negative effect on research productivity. In contrast, quality measures (for example, researcher quality, contractual funding, competitive funding, etc.) generally have positive effects on research productivity.

The implications of these results for research policies mainly affect R&D budget allocations. Due to the scarcity of R&D budgets, funds should be allocated prudently based on R&D performance. Competitive funding may increase gradually, separate from institutional funding. Generally, R&D performance and the institutional quality measures should be the bases for resource allocations to R&D institutions.

### 5.3. Determinants of productivity

#### 5.3.1. Relevance

In this study, we introduced R&D institutions' disseminating productivity as an indicator of their productivity. This measure indicates the relevance of institutional R&D programs in responding to public issues. The measures of relevance or disseminating productivity developed in this study are: nominal numbers of technologies that have been applied and/or commercialized by R&D institutions (desNOM); numbers of technologies that have been applied and/or commercialized by R&D institutions per researcher (desPROD); and ratio of technologies that have been applied and/or commercialized by R&D institutions to new technologies that have been produced (desREL). Based on the results of this study, desPROD was demonstrated to be statistically applicable, as shown in Table 9.

Table 9 shows that the effects were not significant for researcher quality, R&D budget or other control variables on research productivity (desREL). In contrast, the results for desNOM and desPROD showed that the independent variables simultaneously had strong effects on R&D productivity, with $R^2$ values of 0.585 and 0.576, respectively, and significance level of $p < 0.01$. Individually, senRES and RDEX had no significant effects on disseminating productivity. However, both location and age of the R&D institution had strong and significant effects on disseminating productivity. The effects of location and age of R&D institution on disseminating productivity will be discussed in depth in sub-chapters 5.3.3 and 5.3.4.

Another finding of this study is that the domestic technology that has been commercialized in Indonesia is limited. In the last ten years, only 217 new technological products or services, 33% of the total, that were developed domestically by advanced R&D institutions were applied or commercialized in Indonesia, the equivalent of 0.259 products or services per researcher. Of the above number, only 14% have been licensed for commercial cooperation, and the remaining 86% are applied in non-economic schemes.

A previous study revealed a similar result and showed that the weak commercialization of domestic technology was typical in developing countries [23]. This issue is caused by the fact that most inhabitants and the national economies of developing countries are supported by subsistence agriculture [21]. Based on the data on the

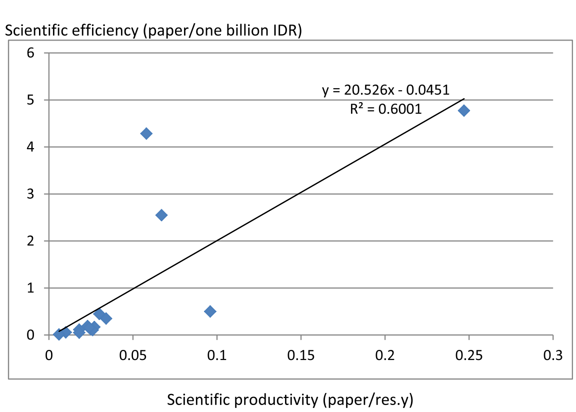



**Fig. 2.** Relation between scientific productivity with scientific efficiency.

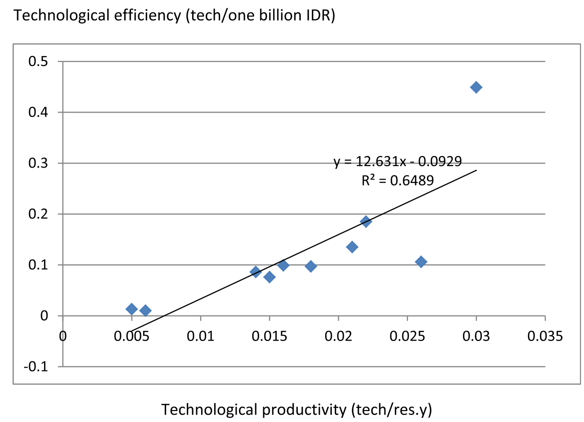



**Fig. 3.** Relation between technological productivity with technological efficiency.

**Table 9**
Regression analysis for alternative dependent variables of disseminating productivity.

| Variable | (1) desNOM | (2) desREL | (3) desPROD |
|---|---|---|---|
| senRES | 0.255 (0.287) | −0.044 (0.926) | 0.297 (0.156) |
| RDEX | 0.033 (0.874) | 0.127 (0.784) | −0.143 (0.486) |
| STAFF | 0.214 (0.279) | 0.299 (0.580) | −0.092 (0.651) |
| RES | −0.067 (0.754) | −0.494 (0.292) | −0.207 (0.329) |
| EX | 0.100 (0.675) | −0.288 (0.674) | −0.158 (0.511) |
| TYPE | 0.175 (0.432) | −0.378 (0.428) | 0.190 (0.397) |
| JAVA | 0.432** (0.036) | 0.396 (0.410) | 0.410** (0.047) |
| AGE | 0.528** (0.014) | −0.016 (0.969 | 0.540** (0.013) |
| F | 9.168 | 0.545 | 8.833 |
| (p value) | 0.003*** | 0.793 | 0.004*** |
| $R^2$ | 0.585 | 0.384 | 0.576 |

Running with SPSS linier regression OLS by Stepwise method. Parentheses are robust significance. For regression column (2) desREL calculation done by Enter method.
*** significance at ($p < 0.01$).
** significance at ($p < 0.05$).
* significance at ($p < 0.10$).

advanced R&D institutions in Indonesia that were observed in this study, 75% of these institutions are related to agricultural commodities. That is, technological products and services that are developed domestically in Indonesia and other developing countries are applied in non-economic schemes as well as in the public sector [23]. Consequently, national innovation systems in developing countries should follow different models from those in developed countries [27].

Depending on the national innovation system as discussed above, the essential indicators are an instrument for analyzing the development of national innovation systems in developing countries will be different from those that are applied to developed countries. The non-economic dimension will be essential in developing national innovation systems in developing countries such as Indonesia. However, innovation in developing countries is more incremental than radical [29], and innovation in informal sectors is more dominant than that in formal sectors [23].

### 5.3.2. Type of institution

Columns (1)–(3) in Table 11 show the relationships between type of R&D institution and research productivity. This study revealed that type of R&D institution has a significant effect on technological and disseminating productivity, finding that R&D-SOs have the strongest effect on R&D productivity compared with other types of R&D institutions. This finding was enhanced by the results in columns (2) and (3) of Table 7 that type of R&D institution has a positive influence to research productivity, especially for the technological and disseminating productivity measures (techPROD and desPROD). This finding indicates that the research productivity of R&D-SOs is higher than that for other types of R&D institutions (see Table 12).

In contrast, according to the scientific productivity measures (sciPROD), as shown in columns (1)–(3) of Table 11, HEIs are more productive than other types of R&D institutions. Based on columns (1) and (2) of Table 10, all independent variables simultaneously had a stronger and more significant effect on scientific productivity for HEIs ($R^2 = 0.695$) than for other types ($R^2 = 0.598$). Individually, the β for the effect of researcher quality on research productivity (sciPROD) for HEIs ($\beta = 0.688$) is stronger than that for other types ($\beta = 0.533$).

However, the negative effect of R&D budget on research productivity is stronger and more significant for other types of institutions than for HEIs. This finding indicates that the negative size effect of research budget on R&D productivity does not occur strongly in HEIs.

This study has revealed, based on the above results, that type of R&D institution had a positive effect on research productivity. It can be concluded that R&D-SOs had the highest research productivity of all institution type. However, for scientific productivity, HEIs performed the best. Generally, this result reconfirms the previous findings [35]. Ref. [19] analyzed the performance of R&D institutions in OECD countries based on econometric analysis and suggested that the effects of publicly funded R&D on productivity growth are larger in countries that devote more of their budgets to universities than to government labs.

Another implication of this result is that fiscal policies for research budget allocations to HEIs may be applied to gain productivity from fundamental research. On the other side, a policy can be considered to drive greater dissemination of research products from R&D-SOs to the public or industry as well as to promote collaboration between R&D-SOs and HEIs outside of Java Island to develop high-priority local commodities. This policy would have two aims: first, to push the research productivity of R&D institutions outside of Java Island; second, to accelerate the application of domestic technology in the public or industry. The remaining research budget to be allocated among PRIs, HEIs, and R&D-SOs should be optimized to enhance research productivity at the national level [36].

### 5.3.3. Location of institution

Columns (4) and (5) of Table 11 show a significant effect of the relationship between R&D institution location and research productivity.

Generally, R&D institutions located on Java Island are more productive than are those located elsewhere in Indonesia, and this result was consistent for scientific, technological, and disseminating productivity. Columns (2) and (3) of Table 7 show the similar result that technological and disseminating productivity were influenced strongly, positively and significantly by being located on Java Island. Simultaneously, institution location and other independent variables had strong and significant effects on technological ($R^2 = 0.538$, $p < 0.01$) and disseminating ($R^2 = 0.576$, $p < 0.05$) productivity. Institution location also had strong and significant individual effects on technological ($\beta = 0.578$, $p < 0.01$) and disseminating ($\beta = 0.410$, $p < 0.05$) productivity.

According to the results in Table 10, especially columns (3) and (4), it can be seen that the individual effect of researcher quality on scientific productivity was stronger for R&D institutions located on Java Island ($\beta = 0.787$, $p < 0.05$) than for those located elsewhere in the country ($\beta = 0.176$, $p > 0.10$).

However, the negative effect of research budget on scientific productivity was stronger and more significant for R&D institutions located outside of Java Island ($\beta = -0.937$, $p < 0.05$) than for those located on the main island ($\beta = -0.149$, $p > 0.10$). These findings indicate that the negative size effect of research budget on research productivity did not occur strongly for R&D institutions located on

**Table 10**
Regression coefficient for R&D determinants.

| Variable | Type of R&D institution | | Location of R&D institution | | Age of R&D institution | |
|---|---|---|---|---|---|---|
| | (1)HEI | (2)Non-HEI | (3)Java | (4)outside-Java | (5) < 15 years | (6) >15 years |
| senRES | 0.688*** (0.005) | 0.535** (0.013) | 0.787** (0.020) | 0.176 (0.315) | 0.388** (0.031) | 0.337 (0.546) |
| RDEX | 0.094 (0.844) | −0.408** (0.047) | −0.140 (0.643) | −0.937*** (0.001) | −0.792** (0.003) | 0.005 (0.988) |
| STAFF | −0.483** (0.028) | −0.018 (0.935) | −0.094 (0.769) | 0.176 (0.350) | −0.009 (0.986) | −0.050 (0.887) |
| RES | 0.318 (0.370) | 0.148 (0.551) | −0.150 (0.599) | −0.026 (0.889) | 0.153 (0.425) | −0.027 (0.926) |
| EX | 0.069 (0.788) | 0.260 (0.341) | −0.013 (0.971) | −0.074 (0.693) | 0.023 (0.911) | 0.256 (0.528) |
| F | 10.240 | 9.650 | 9.790 | 42.818 | 36.688 | 8.255 |
| (p value) | 0.005*** | 0.003*** | 0.020** | 0.001*** | 0.003*** | 0.024** |
| $R^2$ | 0.695 | 0.598 | 0.620 | 0.877 | 0.948 | 0.541 |

Running with SPSS linier regression OLS by Stepwise method. Parentheses are robust significance.
*** significance at (p < 0.01).
** significance at (p < 0.05).
* significance at (p < 0.10).

**Table 11**
Research productivity for each R&D determinants (averaged values).

| Variable | Type of R&D institution | | | Location of R&D institution | | Age of R&D institution | |
|---|---|---|---|---|---|---|---|
| | (1)HEI | (2)PRI | (3)R&D-OS | (4)Java | (5) outside-Java | (6) < 15 years | (7) >15 years |
| sciPROD (pap/res) | 0.180 | 0.09 | 0.120 | 0.176 | 0.150 | 0.192 | 0.126 |
| techPROD (tech/res) | 0.337 | 0.34 | 0.977 | 0.734 | 0.180 | 0.167 | 0.804 |
| desPROD (tech/res) | 0.150 | 0.34 | 0.660 | 0.497 | 0.068 | 0.079 | 0.491 |

**Table 12**
Acronim used in the paper.

| | |
|---|---|
| ARN | National Research Agenda (5 years agenda) |
| BPPT | Agency for Assessment and Application of Technology (PRI-NM) |
| DRN | National Research Council |
| HEI | Higher Education Institution |
| IDR | Indonesian Rupiah |
| LIPI | Indonesian Institute for Science (PRI-NM) |
| MoA | Ministry of Agriculture |
| MoF | Ministry of Finance |
| MoRT | Ministry of Research and Technology |
| MoEC | Ministry of Education and Culture |
| MoDP | Ministry of National Development Planning |
| PRI | Public Research Institution |
| PRI-NM | Public Research Institution as a Non-Ministerial Government |
| PRI-M | Public Research Institution as Ministerial R&D agencies |
| R&D-SO | R&D agencies formed as state owned enterprises |
| RPJPN | National Long-term Development Planning (25 years planning) |

Java Island.

This study revealed that in general, the location of an R&D institution has a strong and significant effect on research productivity. The institutions located on Java Island are more productive than are those in other parts of the country. A previous study [45] showed that human capital and financial development in a given country also have strong effects on R&D intensity. That study found evidence that the effects of institution on research intensity vary in different economies.

Based on the above results, policy recommendations that promote research productivity in R&D institutions that are not located on Java Island have directed their efforts toward increasing researcher quality through training, doctoral education, and participation in research consortia, especially for priority local commodities. However, for fiscal policy, supporting R&D institutions in areas other than Java Island should be considered carefully because increased research budgets are not always followed by increased research productivity. Generally, increasing research budgets tends to be followed by a negative size effect through declining research productivity.

*5.3.4. Age of institution*

Generally, age of R&D institution had a significant effect on R&D productivity. Columns (6) and (7) in Table 11 show that R&D institutions older than 15 years had higher technological (techPROD) and disseminating (desPROD) productivity than did those that were younger than 15 years (established after Indonesia's Reformation Era, in 1998). However, for scientific productivity (sciPROD), institutions older than 15 years showed lower productivity than did institutions that were younger than 15 years.

Column (3) of Table 7 confirms the above results. Regression calculation showed that AGE, simultaneously with other independent variables, had a strong and significant effect on disseminating productivity (desPROD) ($R^2 = 0.576$, $p < 0.01$). Individually, age of R&D institution (AGE) had a strong, positive and significant effect on research productivity ($\beta = 0.540$, $p < 0.05$).

In this study, the regression calculation also split the input data into AGE >15 years and AGE >15 years, as shown in columns (5) and (6) of Table 10. The results show that simultaneously, all independent variables had significant and strong effects on scientific productivity (sciPROD). Similar to the above result, R&D institutions with AGE >15 years had lower scientific productivity (sciPROD) ($R^2 = 0.541$, $p < 0.05$) than did those with AGE < 15 years ($R^2 = 0.948$, $p < 0.01$). Individually, researcher quality and research budget had stronger and more significant effects on scientific productivity (sciPROD) for R&D institutions < 15 years of age than those for institutions over age 15 years.

This study showed that age of R&D institution had significant effects on R&D productivity. Institutions with AGE >15 years had higher technological (techPROD) and disseminating (desPROD) productivity than did those with AGE < 15 years. However, R&D institutions with AGE >15 years had less scientific productivity (sciPROD) than did those with AGE < 15 years.

These findings indicate that the scientific productivity of older R&D institutions, especially HEIs, can be surpassed by that of younger organizations. Ref. [2] also showed that age of institution was negatively correlated with productivity. They argued that the averaged researcher age at older HEIs was higher than the average at younger organizations, and average researcher age had a negative effect on research productivity [2]. With disseminating productivity, age of R&D institution had a positive and significant effect. That is, the increasing age of an R&D institutions will be followed by increased experience, maturity, and competence. In the initial phase, scientific productivity increased; then, in the middle phase, technological productivity increased; and finally, in the end phase, disseminating productivity increased. The older R&D institutions had higher disseminating productivity than did younger ones based on their experience. A resulting policy implication from this finding is to drive technological dissemination mainly for older R&D institutions with high disseminating productivity.

## 6. Conclusions

This study finds new evidence and enhances previous findings related to the determinants of research productivity, especially for R&D institutions in developing countries. The important findings of this study are related to the relationships between R&D activities and socioeconomic development in developing countries such as Indonesia. Some of the conclusions that can be drawn from this study are articulated below.

This study developed “disseminating productivity” as an indicator for research productivity. This indicator is more powerful than the others because it indicates the relevance of R&D activities for socioeconomic development, especially in developing countries. Disseminating productivity measures not only R&D output but also outcomes. In developing countries, technology and R&D are applied not only directly for commercial purposes but also for social uses. This study showed that the domestic technology that had been commercialized in Indonesia was limited. In the last ten years, only 217 new technology products or services, 33% of the total, that were developed domestically by advanced R&D institutions have been applied or commercialized in Indonesia. From the above number, only 14% have been licensed for commercial uses; the remainder, 86%, were applied for social uses. The advanced R&D institutions in Indonesia that were observed in this study are mostly related to agricultural commodities, at 75% of the total. A previous study revealed a similar result and showed that the weakness in commercializing domestic technology was typical for developing countries [23]. This issue is caused by the fact that most inhabitants and the national economies in developing countries are supported by subsistence agriculture [21]. This indicates that technological products and services that have been developed domestically in Indonesia and other developing countries are applied to non-economic schemes as well as to the public sector [23]. Consequently, national innovation systems that develop in developing countries should have different models from those used in developed countries [27]. The non-economic dimension will be essential in developing national innovation systems in developing countries such as Indonesia.

Based on the R&D institutions in Indonesia, this study found new evidence and enhanced previous findings that the effects of researcher quality and R&D budget on research productivity are strong and significant; researcher quality had a particularly strong, significant, and positive effect on productivity. The effect of researcher quality on R&D productivity was the opposite of the effect of researcher quantity. The last measure corresponded to the negative size effect [4,9]. This study also found that R&D budget had a negative, strong, and significant effect on research productivity in a developing country such as Indonesia. This finding is different from that by Defazio et al. (2009); who concluded that the impact of funding on productivity was generally positive. This negative size effect did not occur strongly in HEIs, in institutions that were located on Java Island, or in institutions that were older than 15 years.

According to this finding, it can be understood that size or quantity measures (for example: number of researchers, R&D budget, etc.) generally tend to have a negative effect on research productivity. In contrast, quality measures (for example: researcher quality, contractual vs. competitive funding, etc.) generally have positive effects on research productivity.

This study revealed that type of R&D institution has a significant effect on research productivity. It was found that R&D-SOs have the highest research productivity compared with the other types of R&D institutions. However, for scientific productivity, HEIs performed the best.

Generally, location of R&D institution had strong and significant effect on research productivity. The R&D institutions that were located on Java Island were more productive than were those located elsewhere in Indonesia. This can be understood by the fact that Java Island is more advanced in terms of abundance of inhabitants, infrastructure, IT, energy sources, better-educated human resources, etc. compared with the rest of the country. Java Island makes a high contribution to the national GDP of Indonesia, and a previous study [45] showed that levels of human capital and financial development have strong effects on a country's R&D intensity.

This study shows that the age of the R&D institution has a significant effect on R&D productivity. Institutions older than 15 years had higher technological (techPROD) and disseminating (desPROD) productivity than did institutions that were younger than 15 years; however, the older institutions had less scientific productivity (sciPROD) because increasing age will be followed by increased experience, maturity and competence. In the initial phase, scientific productivity increases. Ref. [2] argued that the average age of researchers at older R&D institutions was higher than that of younger organizations and that average researcher age had a negative effect on research productivity.

The implications of these results on research policy are mainly in the areas of innovation strategy, R&D budget allocation, and human resources development. Technological products and services that are developed domestically in Indonesia and other developing countries are mainly applied in non-economy schemes in addition to the public sector. Consequently, the national innovation systems that are developed in developing countries should use different models from those used in developed countries. The non-economic dimension will be an essential factor in developing national innovation systems in developing countries such as Indonesia.

Due to scarce R&D budgets, funds should be allocated prudently. Competitive funding may increase gradually along with institutional funding. Generally, R&D performance and research productivity should be considered as bases for resource allocation. The balance of research funding should be allocated optimally among PRIs, HEIs, and R&D-SOs to enhance research productivity at the national level. Because HEIs showed the highest scientific productivity, HEIs should have higher budget allocations to gain from the productivity of fundamental research. On the other side, a policy to drive the stronger dissemination of research products from R&D-SOs to the public or industry as well as collaboration between R&D-SOs and HEIs outside of Java to develop local commodities should be considered. To push the research productivity of R&D institutions located outside of Java Island, efforts to increase researcher quality through education to the PhD level, joining in research consortia, and especially, high-priority local commodities should all be considered. In terms of applications in fiscal policy, supporting R&D institutions that are not located on Java Island should be considered carefully. This is due to the finding that higher research budgets are not always followed by increased research productivity.

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