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Using R&D indicators to shape a small island innovation ecosystem

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Abstract: The approaches to formulate effective and evidence-based innovation policies is a question that is often debated amongst researchers, innovators and policy makers. Evidence-based policy making which is based on innovation measurements and indicators is known to have a positive impact on a country's innovation performance. This paper demonstrates the case of the small island developing state of Mauritius where such indicators (R&D expenditure, number of researchers and publications) were used to collect, analyse data via a national survey of different sectors and conduct a bibliometric analysis of the publications output to inform a national Innovation Scoreboard. The use of the findings and insights from these measurements are discussed and how the future R&D and innovation strategies post the COVID-19 pandemic should be further aligned to the country's goals of becoming a blue economy and a regional knowledge hub driving responsible innovation and leadership through its growing innovation ecosystem.

Keywords*: Innovation; evidence-based policies, R&D Expenditure, R&D strategies, publications.*

1 Introduction

The development of statistical measurements to quantify innovation has been widely reported (Arundel *et al*, 2019; Zabala-Iturriagagoitia, 2021; Halaskova *et al*, 2020). Besides a number of country innovation scoreboards, regional and international scoreboards have also been developed such as the European Commission Scoreboard, the African Union Scoreboard or the OECD STI Scoreboard (AUDA-NEPAD, 2019, OECD, 2021). These scoreboards encompass measurements in the field of Education, Research and Development, Science, Business and Intellectual property.

There is limited literature on the measurement of Research and Innovation indicators in Small Island Developing States (SIDS), especially in the region of Africa. Yet, the on-going financial and economic crisis caused by COVID-19 is particularly threatening to SIDS given their inherent vulnerabilities such as scarce land resources, remote location, increased exposure to environmental hazards and climate change. In these conditions, a robust innovation ecosystem is essential to provide better resilience. Mauritius has developed a Mauritian Innovation Scoreboard as part of its National Innovation Framework (Ministry of Technology, Communication and Innovation, 2018). Since the launch of the framework, the rank of Mauritius' Global Innovation Index (GII) has leapfrogged from 82nd position in 2019 to 52nd position. The GII report 2020 attributes the ranking of Mauritius to a "mix of new data availability, data revisions at the source, and performance effects" (Cornell University and WIPO,2020).

Despite its remarkable progress in its Global Innovation Ranking, Mauritius ranks relatively low in some R&D related GII indicators. Out of the 131 ranked countries, the rank of Mauritius tends to be in the lower half of the list for different indicators related to expenditure on R&D, private sector participation in R&D, number of researchers and number of scientific and technical articles.

Hence a national survey based on established methodologies (OECD Frascati Manual, 2015) was conducted to collect ground data on R&D expenditure and number of researchers. It is the first time that such an exercise has been conducted in Mauritius during the financial year July 2019-June 2020. This exercise was coupled with a bibliometric analysis to evaluate the national R&D publication output.

This paper reports on this national R&D survey conducted in Mauritius by the Mauritius Research and Innovation Council. The data was analysed to assess and benchmark the country's R&D performance and recommend strategies for identified gaps.

This paper demonstrates how the use of R&D data can help to consolidate a country's innovation ecosystem and align country goals with Research and Innovation policies.

2 Methodology

The exercise consisted of the collection of data on a number of researchers and research expenditure based on the internationally recognized methodologies developed by the OECD (OECD Frascati Manual, 2015).

Bibliometric analysis is a proven method to assess R&D performance at different levels. This method consists of providing a quantitative analysis of peer reviewed publications. The use of bibliometric analysis using well known data bases such as Web of Science and Scopus has been widely recognized in evaluating Research and Development performance (Franceschet and Constantini, 2011; Baas *et al.*, 2020, Hossain, 2020, Kipper *et al.*, 2020, Zhu and Liu, 2020).While the survey on number of researchers and expenditure would give indications on the inputs of the R&D system of a country, the publications can be considered as an output of the system which can no doubt help to get a more integrated picture of the R&D landscape.

Based on this perspective, during the national survey exercise which was carried out, the collection of data on number of researchers and research expenditure was coupled with a bibliometric analysis of Mauritian publications for the same year. The following were used as input and output to design the exercise, inform the measurements which were carried out and thus feed into the Mauritius national innovation scoreboard.

R&D Input

Number of Researchers and R&D Expenditure for the financial year 2019/2020 were collected in a national survey using standard questionnaires (OECD Frascati Manual, 2015). The following 4 institutional sectors were surveyed: Government, Higher Education, Business Enterprise and Private Non-Profit.

The number of institutions contacted and the response rate for each sector is tabulated below.

Table 1: Survey Universe

Sector	*No of institutions contacted*	*Response Rate (%)*	*Positive Response Rate (%)*
Government	139	82	17.5
Higher Education	53	24	77.0
Business Enterprise	932	34	13.0
Private Non-Profit	140	41	19.0

A positive response rate indicates the percentage of institutions conducting R&D.

R&D inputs were categorised under the following fields:

(1) Natural Sciences
(2) Engineering and Technology
(3) Medical and Health Sciences
(4) Agricultural Sciences
(5) Social Sciences
(6) Humanities

For international comparison, the R&D expenditures are expressed as percentages of National GDP and number of researchers (Full time Equivalent) expressed per million of inhabitants. Expenditure as a percentage of GDP were expressed

as follows: Gross Expenditure (GERD), Government Expenditure (GOVERD), Business Expenditure (BERD), Higher Education Expenditure (HERD), Private Non-Profit Expenditure (PPERD).

R&D Output

The number of publications for the years 2016 to 2020 were evaluated using the Scopus database.

Publications were classified into fields of R&D as per the Scopus Classification. The number of publications in Ocean Sciences was also evaluated. The authors' affiliations for publications analysed were used to capture different kinds of partnerships including Business/ Higher Education and international collaborations.

The performance of Mauritius compared to other specific SIDS, African countries and more innovative states was conducted.

3 Results

Trends in R&D Expenditures

Table 2 represents statistics on R&D expenditures, with regards to the sources and recipients of funds.

Table 2: Sources and Recipients of Fund in National Currency, MUR

	Recipient of Funds (Sector of Performance)				
Sources of Funds	**Business enterprise**	**Government**	**Higher education**	**Private non-profit**	**Total**
Business enterprise	183,130,227		55,000	49,017,888	232,203,115
Government	103,631,484	932,307,603	271,961,077	19,586,489	1,327,486,653
Higher education (Public + Private)		125,000	120,441,137		120,566,137
Private non-profit		5,000,000		3,392,010	8,392,010
Funds from abroad	67,745,145	43,378,250	581,818.00	27,816,696	139,521,909
Total R&D Expenditure	354,506,856	980,810,853	393,039,032	99,813,083	1,828,169,823

The total R&D expenditure on R&D in Mauritius amounts to around MUR 1.8 billion, which represent 0.37% of GDP, a low figure considering the targeted R&D spending of 1% of GDP for African countries as endorsed by the African Union's Executive Council in 2006 (African Union, 2007).

72.6 % of the total R&D funds comes from the Government sector while the Business Enterprise contributes only 12.7% of total R&D expenditure.

Table 3: Comparison of R&D expenditures with other countries

	Expenditure on R&D as % of GDP				
Countries	**BERD**	**GOVERD**	**HERD**	**PNPERD**	**GERD**
Mauritius* (2019)	**0.07**	**0.2**	**0.08**	**0.02**	**0.37**
Japan (2018)	2.6	0.25	0.38	0.04	3.28
Finland (2018)	1.81	0.23	0.7	0.02	2.76
Norway (2018)	1.08	0.28	0.71	na	2.07
Singapore* (2017)	1.15	0.21	0.56	na	1.92
Australia (2017)	0.99	0.19	0.64	0.06	1.87
Estonia (2018)	0.59	0.16	0.63	0.02	1.4

Portugal (2018)	0.68	0.08	0.57	0.02	1.35
Ireland (2018)	0.86	0.05	0.24	na	1.15
South Africa (2017)	0.34	0.19	0.24	0.03	0.83
Indonesia (2018)	0.02	0.16	0.05	na	0.23
Trinidad and Tobago* (2018)	0.01	0.07	na	na	0.08
Sweden (2018)	2.35	0.12	0.84	na	3.31
Egypt (2018)	0.03	0.2	0.49	na	0.72
Ethiopia (2017)	0.01	0.18	0.08	0.01	0.27
Botswana (2013)	0.1	0.07	0.27	0.1	0.54
Ghana (2015)	na	0.08	0.265	na	0.38
Mozambique (2015)	0.01	0.16	0.14	0.07	0.38
Uganda (2014)	0.01	0.07	0.07	na	0.14
Cuba* (2018)	na	na	na	na	0.54
Papua New Guinea*(2016)	na	0.02	0.01	na	0.03
Seychelles* (2016)	na	0.2	0.01	0.02	0.22
Denmark (2018)	1.95	0.09	0.98	0.01	3.03
Austria (2018)	2.22	0.23	0.71	0.02	3.17
Germany (2018)	2.16	0.42	0.56	na	3.13
Israel (2018)	4.36	0.08	0.46	0.05	4.94
Republic of Korea (2018)	3.64	0.46	0.37	0.06	4.53

Sources: UNESCO Institute of Statistics database (2021) and African Innovation Outlook III, AUDA-NEPAD (2019)) (b) na means non-available. (c) * SIDS (d) Figures in bracket is year for which data is available

SIDS and African member states tend to invest less in R&D This is confirmed by an average GERD of 1.03% reported for SIDS by the UIS (UIS, 2021). These could be due to the multiple challenges that these countries are faced with, including water scarcity, climate change, food crisis, poverty, epidemics and for SIDS the additional challenges include their small sizes and remote locations. In such a situation, it can be argued that the country priorities do not include R&D but at the same time it is acknowledged that R&D could help in alleviating poverty and have a positive impact on socio economic development.

When compared to other SIDS, Mauritius has a higher GERD except for Singapore. This could be due the National Innovation Program which has involved an additional budget of MUR 125 million to MUR 150 million annually over the past three years and a National Research Fund of MUR 50 million since 2018 for academic research in Universities.

Business Investment

Innovative economies have a GERD exceeding 1.15%, with the BERD being higher than GOVERD or HERD. In developed economies such as Japan, Norway, Finland and Singapore, it is clear the percentage of R&D funding coming from business is much higher than government investment in R&D with BERDs exceeding 1% and even exceeding 2% in some cases. The trend for African states including Mauritius is very different with BERDs being generally less than 0.05%, Mauritius is doing slightly better with a BERD of 0.07%. In the African region, South Africa topped the list in Africa with a BERD of 0.34%.

Grants and tax incentives are recognised as effective policy tools to increase business participation in R&D. It is also known that direct Government funding has a positive effect on business financed R&D (Falk, 2007, Guellec and Van Pottelsberghe De La Potterie, 2004). Countries with strong patent rights are also known to have high R&D intensities (Falk, 2007). Hence, since 2018, the Government of Mauritius has taken a number of measures to increase business expenditure in R&D. These include the Public-Private Partnership (PPP) Models as well as Research and Innovation Funding Schemes with a high degree of Internationalization (Ministry of Technology, Communication and Innovation,2018). The legal framework surrounding Intellectual Property Rights (IPR) is being reinforced and, regulatory frameworks to encourage investment in R & D are considered. Since 2017, new policies such as tax incentives have been introduced to motivate local and foreign companies to invest in R & D in Mauritius (Ministry of Finance and Economic Development, 2017). On 30 July 2019, the Mauritius Parliament passed the Industrial Property Bill 2019, which aims to update and strengthen protection of intellectual property rights in a way that is harmonised to meet the challenges of a globalised industry. The proclamation of the IPR bill

should pave the way for businesses in Mauritius to invest funds in R&D without the fear of competing companies to take advantage of their investment.

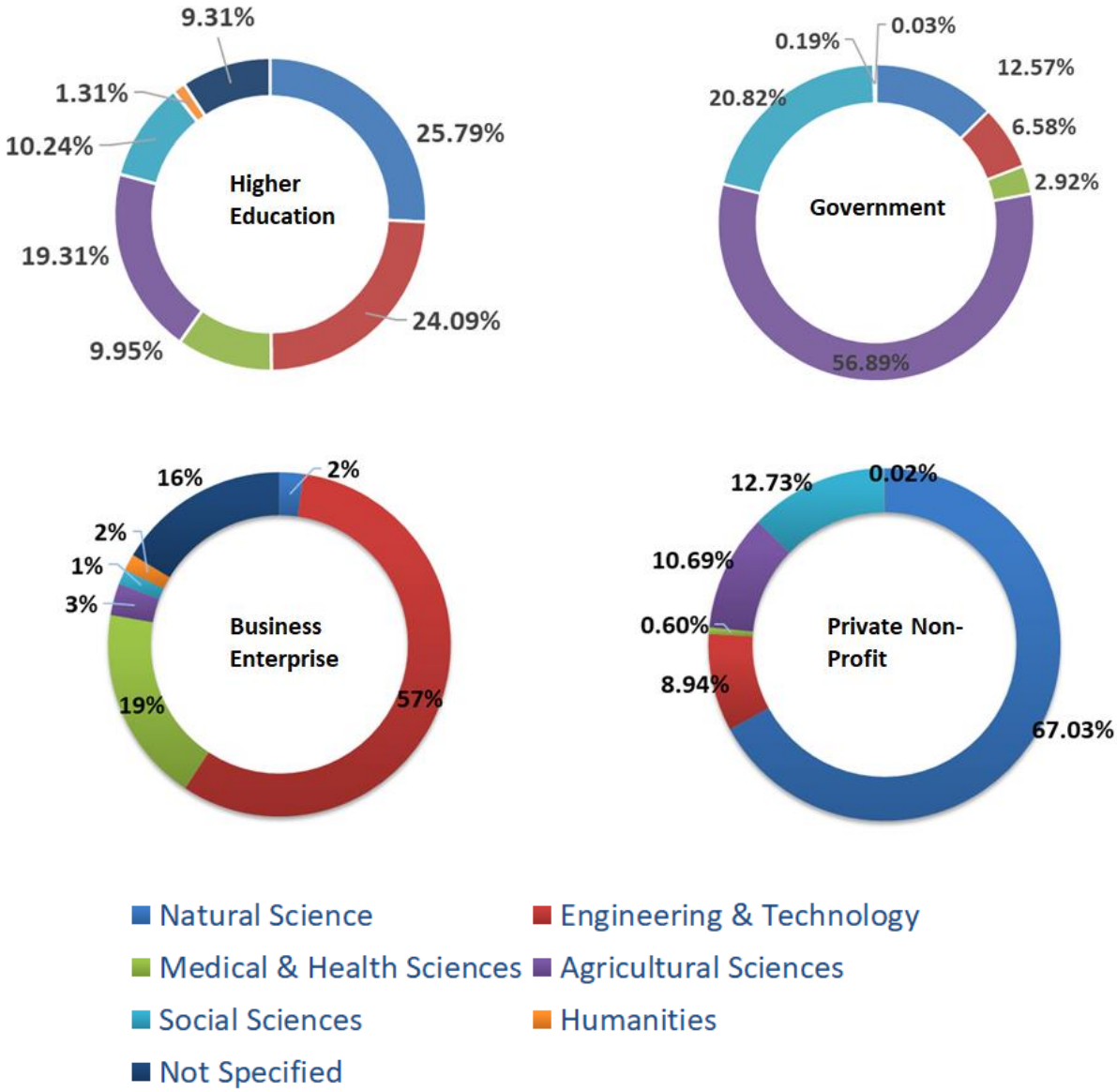

Figure 1: Expenditure for the 4 surveyed sectors by Field of Research (%)

Different R&D priorities were identified for the public, higher education and business sectors with fields with highest investment being Agricultural and Veterinary Sciences, Natural Sciences and Engineering and Technology respectively (Figure 1). This could indicate a potential mismatch between research needs of the business sector and the research expertise and activities in the government and higher education sectors. This is further confirmed by the low percentage of collaborative publications between the business and government sector (Table 7). It is crucial for the government to establish public private fora to address this mismatch and synergise R&D efforts at national level.

Trends in Human Resources involved in R&D

Table 4: Researchers by gender and Sector of employment

	Male		Female	
	HC	**FTE**	**HC**	**FTE**
Government	273	142.92	246	130.40
Higher Education	453	173.43	403	173.16

Business Enterprise	73	41.92	34	26.51
Private Non-Profit	20	4.95	25	6.68
Total	819	363.22	708	336.75

HC: Headcounts; FTE: Full Time Equivalent

The total number of researchers amounts to 699.97 FTE (553 per million of inhabitants). The highest number of researchers is registered in the Higher Education Sector and the lowest is in the Private non-profit sector, representing only 1.67 % of the total researchers in Mauritius. The number of male to female researchers is approximately 1:1 in all sectors, except in Business sector, where there are about 2 male researchers for 1 female researcher. When compared to other countries in Africa, Mauritius is faring well with a total number of 553 researchers FTE per million of inhabitants, which is higher than Ethiopia, Botswana, Ghana, Mozambique and Uganda (Figure 2). However, compared to SIDS like Singapore and Seychelles, the mass of researchers in Mauritius is 3 to 7-fold less. Likewise, in the developed economies like Asia and Europe, the difference is 10 to 16 times more compared to Mauritius.

Figure 2: Researchers per million of inhabitants in FTE for some countries

The reasons for the lower number of researchers could be linked to the needs of the job market as well. A low investment in R&D by business (Table 2) indicate that there is not a high demand for researchers on the job market. In fact, 40% and 56.1% of researchers in Mauritius are employed by the Higher Education and Government sectors respectively (Table 4).

Table 5: Share of female researchers

Countries	% Female Researchers (FTE)
Estonia (2017)	40.7
Portugal (2017)	43.1
Ireland (2017)	35.3
South Africa (2017)	44.4
Senegal (2015)	30.2
Mauritius (2019)	48.1
Indonesia (2017)	43.7
Trinidad and Tobago (2017)	54.6

The percentage of female researchers in Mauritius is 48.1, which is higher than some of the countries being assessed (Table 6) but less compared to Trinidad and Tobago.

Figure 3: Mauritius Researchers by Gender and Field of Research (FTE)

Comparing the fields of research, it is observed that men are more predominant in Natural Sciences and Engineering and Technology. The lower percentage of women researchers in Engineering and Technology and Natural Sciences is linked to the gender gap in STEM Education which was reported to be more acute in Physical and hard Sciences and is apparent as early as in secondary education (Madhou *et al*., 2019). Similar trends have been reported in Great Britain, Netherlands, and Egypt among other countries (Koblitz, 2016; Wyer *et al*., 2014). Gonsalves (2014) accounts this gap to the inherent tension between femininity and Physics and the constant struggle for women to be recognized simultaneously as women and physicists. Interventions as early as in the education system might be necessary to encourage more girls to enrol in Engineering and Technology subjects which should result in more women engaging in this field.

The gender diversities have also been evaluated in terms of the professional qualifications of the researchers. For this purpose, Headcounts were used for comparison. Overall, it has been found that out of the 1527 mass of researchers, 608 researchers possess a Master's degree and 310 have pursued doctoral studies. However, within each type of qualification level, there is no significant gender variation, with a male to female ratio ranging from 1.1 to 1.4.

Bibliometric Analysis

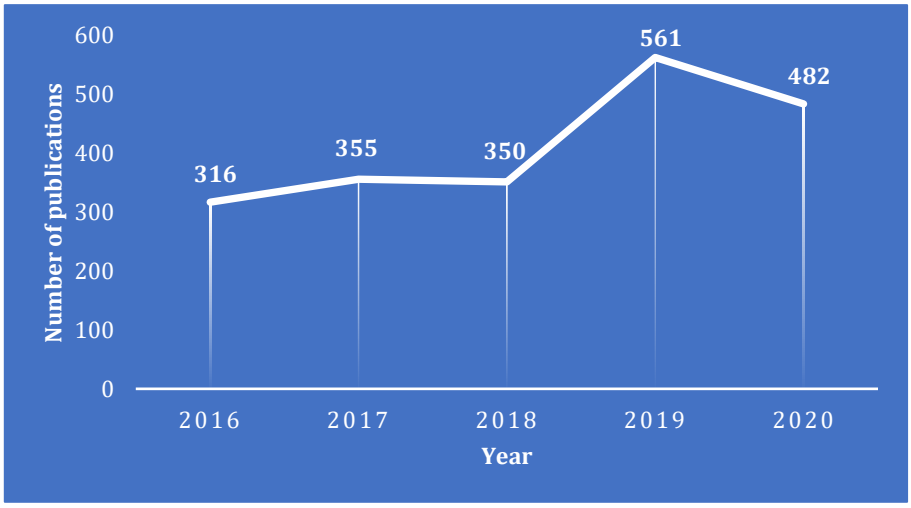

Figure 4: Evolution in number of publications for the years 2016 to 2020
Source: (Scopus, 2016-2020)

The yearly R&D publication output ranged from 316 to 561 in the years 2016 to 2020; with a tendency to increase with time.

Figure 5: Sources of publications for the years 2016 to 2020
(Scopus, 2016-2020)

Most publications (85%) came from the Higher Education Sector. The percentages for the government, business and private non-profit sectors ranged from 2% to 7%.

Figure 6: Average number of publications by fields of research for 2016-2020 (Scopus, 2016-2020)

The highest percentage of publications were in Engineering, Computer Science and Agricultural and Biological Sciences.

Figure 7: Number of publications in ocean sector for years 2016 to 2020 ((Scopus, 2016-2020)

Since the Government is promoting the ocean sector in Mauritius, special attention was given to the publications related to the ocean sector. Ocean –related publications ranged from 5% to 7% from 2016 to 2020.

The percentage of ocean-related publications for the year 2020 for the Republic of Mauritius was compared to other countries such as Seychelles (SIDS country) and Iceland which is one of the leading countries in ocean economy.

Based on the data, it can be observed that 50.5% of the publications of Seychelles is ocean-related whereas only 6.2% of the publications in Mauritius is in the ocean sector.

Table 6: Comparison of Mauritius with other countries for year 2020

Country	Percentage of ocean-related publications
Seychelles	50.5
Iceland	15.6
Mauritius	6.2

(Scopus, 2020)

These figures call for a strengthening of the R&D in the ocean sector for Mauritius to attain its vision of becoming a Blue Economy.

In depth bibliometric analysis

An in- depth analysis was also conducted to capture collaboration between sectors and between institutions within the same sector. Two types of collaboration were investigated for publications for the year 2020. The types of collaborations were captured using the affiliation institutions and organisations and affiliation countries of authors for each publication.

Local collaboration for Mauritian publications (2020)

89% of publications emanated from single institutions/organisations. The remaining 10.6% publications was classified by the type of collaboration.

Table 7: Local collaboration for Mauritian publications for year 2020

Type of authorship	**Percentage of publications**
Higher Education-Higher Education	4.3
Government -Higher Education	3.1
Higher Education-Private Non-Profit	1.0
Higher Education-Business	1.0
Business-Business	0.6
Government-Private Non-Profit	0.4
Business-Private Non-Profit	0.2
Government-Government	0.0
Government-Business	0.0
Others	0.4

Source: *(Scopus, 2020)*

No collaborative publications for government-government and government-business partnerships were recorded. This calls for the establishment of collaborative platforms to allow intersectoral collaboration.

International partnerships by continent

63.1% of publications in the year 2020 in the Republic of Mauritius had at least one international collaborator. Figure 8 shows the percentage of international publications for different continents.

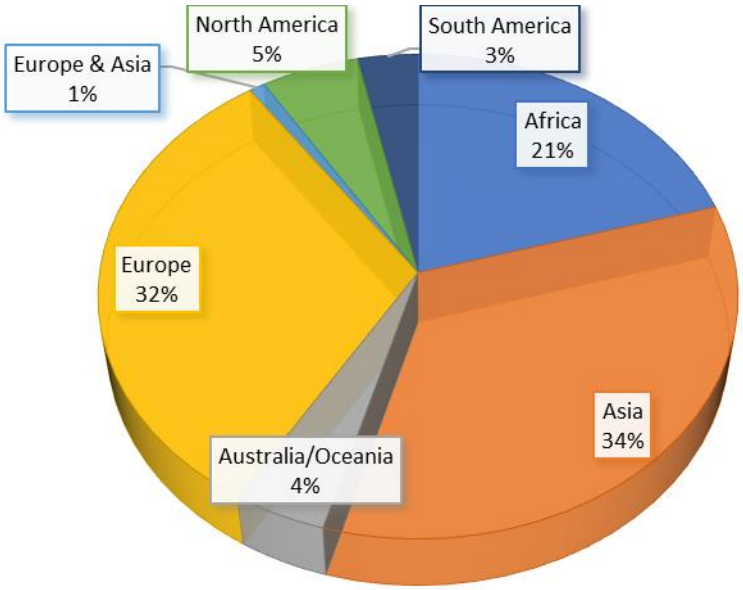

Figure 8: Classification of international collaborative papers of Mauritius
Source: (Scopus, 2016-2020)

Comparison of number of publications with other countries

From Figure 8, it can be observed that Mauritian authors collaborate mostly with authors from Asia followed by Europe and Africa.

Mauritius lies in the middle of the Indian Ocean, some 1,100 kilometres away from Madagascar and 2,300 kilometres from mainland Africa. It has poised itself to become a knowledge hub in the region and forge its partnerships with Africa. Yet, a bibliometric analysis of local publications in 2020 revealed that only 21% of publications with an international counterpart involved an African country (Figure 8). This calls for special Research and Development grants to be formulated to allow Mauritius Africa partnerships in R&D.

Table 8: Comparison of Mauritius with other countries and GII ranking of scientific and technical publications for year 2019

Countries	Number of publications (2019)	GII ranking for sub-indicator on scientific and technical publications
Mauritius	561	77
South Africa	28,455	46
Seychelles	58	Not found in GII
Switzerland	49,881	3
Singapore	23,546	31

Source: (Scopus,2019 and Cornell University and WIPO, 2020)

Countries with a high number of publications has a better ranking in the Global Innovation Index for Scientific and technical publications. On the other hand, the number of publications for Mauritius is relatively low, which reflects the low GII ranking for Scientific and technical publications.

4 Recommendations and concluding remarks

This study is a first of its kind in Mauritius and has demonstrated the feasibility, practical application and use of a system of measurements based on R&D indicators as a policy tool with regards to government/business partnerships, gender disparities and international collaboration.

It is recommended to conduct the survey exercise discussed in this paper annually to follow the evolution of the different R&D indicators and to assess the impact of different policy measures. The learnings from this initial national survey can also be used to further develop and optimise the chosen R&D indicators to align with the specific challenges and opportunities in a SIDS context.

It would be useful to also introduce research performance indicators to track the performance of funded initiatives over time. These could include measurements such as published work or generated IP from funded work. This will allow policy makers to make investment decisions on different initiatives as well as enabling Mauritius to optimise the capability of its Innovation Scoreboard in driving responsible innovation leadership as a small island developing state which seeks to grow and nurture its innovation ecosystem at various societal levels.

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Which areas/questions do you want feedback on at the event?

Insights on measurements of R&D indicators would be useful, especially for groups familiar with the collection and analysis of R&D indicators. Comments from policy makers with experience on use of performance research indicators and measuring impacts of policy measures would be helpful. There is not much literature available in research journals on Africa or SIDS, the advice on editors of Scientific Journals will help us on how to publish this study.