A Pilot Study for the Evaluating Economic and Societal Impact of Engineering Research

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Abstract

Quantitative estimation of research societal and economic impact remains an ongoing issue. This is due to the difficulty to attribute specific economic or societal impact to particular research activity. Nevertheless, evaluating research impact is necessary to justify research spending especially for engineering research studies, as they are generally more costly than humanities or social studies for example. This work considered research impact evaluation in NSF (The National Science Foundation in the USA), EPSRC (Engineering and Physical Sciences Research Council in the UK), and TRC (The Research Council in Oman) to propose a low-cost survey-based approach to evaluate the engineering research impact. A questionnaire was developed and distributed to all faculty staff at the Department of Mechanical and Industrial Engineering at Sultan Qaboos University (SQU) to assess their recent research impact in the years 2016 and 2017. The evaluation was carried at three levels; knowledge, societal, and economic impact. The results of the study were compared with an independent study produced by an international consultancy group. This study offers an important contribution to the subject of evaluating impact factors of engineering research in Oman.

Keywords: SQU; Societal Impact; Socioeconomic Impact; Knowledge Impact; National Science Foundation(USA); Engineering and Physical Sciences Research Council (UK); RAND Corporation (USA); The Research Council (Oman)

دراسة استطلاعية لتقييم الأثر الاقتصادي والمجتمعي للبحوث الهندسية

مصعب عبدالله زروق

الملخص:

لا يزال التقدير الكمي للأثر الاجتماعي والاقتصادي للبحوث يمثل مشكلة مستمرة. ويرجع ذلك إلى صعوبة إسناد تأثير اقتصادي أو اجتماعي محدد إلى نشاط بحثي معين. ومع ذلك، تبقى معرفة جدوى البحث ضرورية لتبرير الإنفاق البحثي خصوصًا للبحوث الهندسية والتجريبية، التي تعد أكثر تكلفة من الدراسات الإنسانية أو الدراسات الاجتماعية على سبيل المثال. هذا البحث أخذ في الاعتبار المعايير المستخدمة لتقييم أثر البحوث في كل من المؤسسة الوطنية للعلوم في الولايات المتحدة الأمريكية، ومجلس أبحاث العلوم الهندسية والفيزيائية في المملكة المتحدة، ومجلس البحث العلمي (عُمان). ومن ثم يقدم هذا البحث مقترحا منخفض التكلفة وفعال ويعتمد على المسح فقط لتقييم الأثر البحثي للبحوث الهندسية. تم تطوير استبيان وتوزيعه على جميع أعضاء هيئة التدريس في قسم الهندسة الميكانيكية والصناعية بجامعة السلطان قابوس (SQU) لتقييم تأثير بحوثهم في عامي ٢٠١٦ و٢٠١٧. وقد أجري التقييم على ثلاثة مستويات؛ تقييم الأثر المعرفي، والأثر المجتمعي، والأثر الاقتصادي. تمت مقارنة نتائج الدراسة بدراسة مستقلة أعدتها مجموعة استشارية دولية وأظهر ذلك توافقا كبيرا في النتائج. تقدم هذه الدراسة مساهمة مهمة في موضوع تقييم الأثر الاقتصادي والمجتمعي للبحث الهندسي في عمان.

الكلمات المفتاحية: الأثر المجتمعي، الأثر الاجتماعي – الاقتصادي، الأثر المعرفي، مؤسسة العلوم الوطنية (الولايات المتحدة الأمريكية)، مجلس بحوث العلوم الهندسية والفيزيائية (المملكة المتحدة)، مؤسسة راند (الولايات المتحدة الأمريكية)، مجلس البحث العلمي (عُمان).

1. Introduction

The need to develop high-quality measures for research impact cannot be overemphasized. For example, in the United States of America, The National Science Foundation (NSF) funds research and education in most fields of science and engineering. NSF receives approximately 40,000 proposals each year of which approximately 11,000 are funded. All NSF proposals are evaluated through the use of two merit criteria; intellectual merit or the potential to advance knowledge, and broader impact merit which is the potential to benefit society and contribute to the achievement of specific, desired societal outcomes (About NSF, 2019). Despite the focus of NSF on impact, quantifying these impacts remains an issue (NSF Merit Review Criteria, 2011) and there is a continuous pressure on NSF to justify public expenditure on research (Roessner et al. 2010). In the United Kingdom the government's expenditure on research and development (R&D) was £10.3 billion in 2016 only in science, engineering and technology (SET) sector, which is equivalent to £3 per week for each person in the UK (Office for National Statistics, 2016). With this large amount of money spent on research; UK public opinion still thinks that research has a good impact on the economy and growth of the country. Based on 1,749 UK adults survey, only 4% think that scientific research makes no direct contribution to economic growth in the UK. According to (Graeme, 2014), only 11% think that government funding for science should be cut because the money can be better spent elsewhere (Graeme, 2014). Data showed that UK government expenditure on R&D, as a percentage of GDP, would need to rise by 30 percent to reach German levels and 50 percent to reach US levels (Reid, 2014).

In all, research impact is the only tool that could tell us how much we should spend on research and how wise we are spending on research. Also, now most of the research proposals are requested to provide evidence for potential societal and economic impacts. Research councils such as EPSRC (Engineering and Physical Sciences Research Council) in the UK develop certain indicators to measure the economy and societal impact of their funded research and they produce annual impact reports (EPSRC Impact Report 2017). Research spending competes with other areas of expenditure at the government, institutions, and companies level. For example, how much money of the public fund can be spent on research? How much money universities should allocate for research? And

how much money companies should invest in R&D (research and development)? Even in cases where there are more research proposals than the allocated fund, on what bases these proposals can compete? Measuring research impact is a tool to answer all the aforementioned questions. Research usefulness can be assessed based on its contribution to the economy, society, or advancement of knowledge. These three areas are known as the scope of research impact. Over time, people attempt to develop indicators to measure research impact but these indicators are still not quantitative tools that could perfectly measure research impact. For example, no tool could tell us how much money research will make, or how much, in numbers, research has contributed to society or the advancement of knowledge. Let alone the interaction between these impacts is another issue. Scientometrics and problems associated with impact measurement were adequately discussed concerning the nature of research in science and how to develop valid and reliable indicators (Bornmann, 2017). Challenges associated with understanding and evaluating research impact were deeply discussed in (Penfield et al. 2014) such as time limitation for impact evaluation and the continuous nature of measuring impacts. There is also an issue with the cost of collecting more accurate and quantitative data that reflects the research impact (Roessner et al. 2010). Getting evidence that links research to its impact is a huge challenge (Penfield et al. 2014). In this work, the author attempts to develop a low cost and comprehensive indicator to evaluate the research impact at university on society, economy, and advancement of knowledge. This evaluation is based on a questionnaire distributed to all researchers at the mechanical and industrial engineering department at SQU. The author developed his own questionnaire to assess the impact of research produced by faculty staff in the Department of Mechanical and Industrial Engineering at Sultan Qaboos University (SQU) in the years 2016 and 2017. These survey questions were extracted from commonly adopted indicators for research impact in literature.

2. Practices of research impact evaluation in Oman:

At this stage, one has to mention the role of funding bodies in Oman concerning the performance of research and its impact evaluation. The author will consider The Research Council (TRC) which is the main funding body in Oman as it plays an important role

in implementing the national research strategy (TRC, 2018). TRC supports four research funding programs; FURAP (Faculty Mentored Undergraduate Research Award Program), Open Research Grants, Graduate Research Support, and Strategic Research Grants. In the evaluation criteria, little value is given to the societal and economic impact of the proposals. For example; in the FURAP funding program the applicability and relevance of the proposal to Oman's socioeconomic development and related public policies are only given 5% of the total evaluation criteria (TRC FURAP, 2013). For the Graduate Research Support, applicability and relevance to Oman represent one of five evaluation criteria (SQU, 2018) In the Open Research Grants, 50% of the evaluation criteria is given to the quality of the research proposal and 50% is given to the potential outcomes of the proposal. Out of that 50% for the outcomes, only one-ninth of the criteria is given to applicability and relevance to Oman's socioeconomic development and related public policies (TRC, 2014). Another big project is funded also by TRC is "Smart City Platform". The main drawback of the evaluation criteria for publication based research– from the author perspective – is that 10% only of the evaluation criteria is given to the relevance to the local context (e.g. to what extent the proposed research is relevant to the local setting, Omani environment, Oman institutional practices, sample or case study being based in Oman) (TRC, 2018). Renewable Energy Strategic Research Program which is also funded by TRC contains eleven criteria for evaluation. None of them has to do with the potential economic impact on Oman (TRC, 2016).

In SQU internal research grant, 9% or one-eleventh of the evaluation criteria are given to the anticipated impact of the proposed work on issues of strategic importance to Oman or the Omani society (SQU, 2019).

The above discussion shows that no enough weight is given particularly to the research economic and societal impact. More importantly, there are no local direct measurable indicators to evaluate these impacts. Up to the author's knowledge, there was only a single attempt to develop measures to evaluate the societal and economic impacts. This attempt came as a request from TRC to RAND Europe to develop a research impact performance management system to help with the continuous assessment of its sponsored research impact and performance improvement. RAND Europe is an independent not-for-profit research institute whose mission is to help improve policy- and decision-making through research and analysis. The report produced by RAND Europe presented some quantitative measures for the performance of the research funded by TRC (Krapels, 2015). These indicators were applied in the report to the number of TRC funded research and the results will be presented later and compared with the results reported in this work. There is no indication from the TRC website that the council adopted these indicators. This work presents a survey to evaluate the research impact at Sultan Qaboos University (SQU). Carrying out this survey at Sultan Qaboos University gives a good general overview of research impact in the whole country (Oman) since the most frequently acknowledged institution from Oman is Sultan Qaboos University and for the last 25 years, the Sultan Qaboos University (SQU) has been the largest producer of research output in Oman and is also the main institution for collaborations (Krapels 2015). In this research, the author developed some specific questions to get a quick but overall view of the research impact (shown in the appendix: Table.2).

3. Examples of pre-research and post-research impact evaluation:

This section generally reviews the practices in research impact evaluation at the proposal stage (pre-research stage) and post-research impact. The review for research impact at proposal level was applied to NSF and EPSCR, while the after research impact evaluation was demonstrated from the Technopolis group report 2015 (Rosemberg et al. 2015) for assessing the economic returns of engineering research in the UK. Technopolis is a consultancy group based in the UK that focuses on the evaluation of science, technology, and innovation.

In the United States, The National Science Foundation (NSF) funds research and education in most fields of science and engineering. All NSF proposals are evaluated through the use of two merit criteria; intellectual merit (potential to advance knowledge) and broader impact merit (potential to benefit society and contribute to the achievement of specific, desired societal outcomes). Examples of broader impact: (through the research itself, through activities that are directly related to specific research projects)
How well does the research activity promote teaching, training, and learning? (e.g. teaching of science, math, and engineering at all educational levels, training and/or professional development of teachers, developing research-based educational materials,…etc.)

How well does the proposed activity broaden the participation of underrepresented groups (e.g., gender, ethnicity, disability, geographic, etc.)?

To what extent will it enhance the infrastructure for research and education, such as facilities, instrumentation, networks, and partnerships? Participation in conferences, workshops)

Will the results be disseminated broadly to enhance scientific and technological understanding? (e.g. Increasing collaboration between academia and industry; partnership with museums, nature centers, science centers, libraries; presenting to policy-makers, members of Congress, industry, and broad audiences; publishing in diverse m

What may be the benefits of the proposed activity to society? (e.g. partnership with federal agencies and private sector; provide information for policy formulation by Federal, State or local agencies; increasing public scientific literacy; development of a globally competitive STEM workforce; Increasing the United States' economic competitiveness; public involvement and dissemination of results to public;)

The Engineering and Physical Sciences Research Council (EPSRC) is the UK's main agency for funding research in engineering and the physical sciences. EPSRC identifies pathways to impact as an essential component of a research proposal and a condition of funding. Applicants are required to clearly outline the potential impact specifically related to their work, otherwise, applicants will be asked to revise the Pathways to Impact and the proposal will only be funded once that acceptable revision has been received. The areas of impact evaluation cover mainly academic beneficiaries (knowledge advancement), and societal and economic impact: Who might benefit from this research and how? And who are collaborators and how applicants are going to work with them to shorten the time between discovery and use of knowledge? A special concern is given to national importance of the research: why it's important for their research to be supported by the UK taxpayer by contributing to current or future UK economic success and how it might address key UK societal challenges (EPSRC, Preparing new proposals to include national importance). The diagram in Figure.1 in the appendix illustrates possible pathways to impact.

An example of post-research assessment of economic impact can be seen in the final report prepared by the Technopolis group in March 2015 which was prepared with the close support of the EPSRC and the Royal Academy of Engineering (Rosemberg et al. 2015).

514 individual REF2014 (The Research Excellence Framework 2014) impact case studies from 46 different HEIs (Higher Educations Institutions) regarding the economic and societal impact of engineering research conducted in the UK over the past 20 years. The report shows the impact across five economic sectors: aerospace and satellite, automotive, construction, live science, and wind energy (which represent 71% of EPSRC engineering funding in 2014.

This useful and huge study was able to partially evaluate the impact of engineering research numerically but it could not give a full numerical reading of the research impact. For example: The study showed numerically the economic and societal impacts of engineering such as the growth of GDP or GVA; investment in R&D; innovation-related income; attraction of engineering facilities and business to investment, employment, and workforce; exportation of engineering related products and services from engineering-related sectors; contributions made by SMEs and micro-companies; operation of government work; policymaking (e.g. in flood research, health-related issues, security..etc.). the study was able to relate even engineering qualifications and personal income and employment level. These are considered to be direct and quantified the economic and societal impact of the engineering field but the still can't be regarded as engineering research impacts unless research impact and contribution are directly evaluated from the engineering field itself.

The study demonstrated the economic outcomes of the overall research activities in wide-area (e.g. automotive industry research). It relates the overall result of the research conducted in these areas directly to monetary value but it was not able to work out the contribution of every research.

The study presented a few cases where specific engineering research has resulted in measurable and calculable economic returns but still was not able to demonstrate this for every single research. These few cases reported have led, for example, to:

Increases in productivity and competitiveness citing examples of research that led to the development/implementation of new industrial processes or techniques and which have (e.g. Development an algorithm that has been used to design the composite wing skins, which resulted in the impact of direct saving of 1.0 ton of fuel per typical flight compared with current metallic skins).

New or increased economic activity including research that led, for instance to the launch of new products,

new sales, creation of spin-outs, and new jobs. These can be quantified by evaluating the annual sales of a new product or savings realized through the implementation of a new process or tool, (e.g. Lab-on-a-chip technologies deliver diagnostic tools for infection and disease which has led to three spin-out companies that have secured a total of 2.3M sterling in venture funding)

Better provision of public services (e.g. Management of discoloration in drinking water distribution systems which has led has safeguarded water quality delivered to the public and has delivered substantial economic savings, support techniques for online child protection which led to an impact on law enforcement agencies, development of a new tool for assessing and managing risks associated with mental health problems

4. Survey method

At the university level, there have been many attempts to assess university impact and different models were developed for this purpose (assess). Assessing the impact is based on either a survey approach or case study and the same can be extended to evaluating research impact. Single-case studies generally provide more reliable results but they lack generalizability, while survey-based studies can provide a model that can be applied to a range of studies but it can suffer from bias and ignorance of respondents (Drucker and Goldstein 2007). Our approach here is based on survey analysis. The questionnaire used in this study was developed by the author in English and it was distributed to the whole academic staff at the department of mechanical and industrial engineering at Sultan Qaboos University (SQU). The questionnaire was handed in person to the target group. 28 of the 29 academic staff responded successfully to the questionnaire with an almost 97% response rate, and 54 questionnaires were received. It is worth mentioning that this survey represents a continuation of a previous analysis which was focusing on the research budgeting within the same department (Zarog 2019). Some follow-up attempts were made to ensure this high response percentage but all the staff showed a willingness to fill in the questionnaire. Every staff was given two questionnaires, one of which is concerned with research that has led to a recent publication in a peer-reviewed journal, and the second questionnaire is about recent research that has led to a conference publication. The author has referred to the recent publications lists (2016 and 2017) of the department of mechanical and industrial engineering and picked

one journal paper and one conference paper for almost each staff member. Since the questionnaire requires knowledge about the research details (such as cost and funding, collaboration, people involved, etc.), the author selected only those papers were the academic staff is the first author. The questions were clear and direct as shown in Table.1 in the appendix.

5. Evaluating impacts

5.1 Economic impact

The economic impact is very crucial when evaluating engineering research. The main challenge in evaluating economic impact is to develop relevant impact indicators that could be quantified relatively easily and which can be feasibly converted to monetary terms (Roessner et al. 2010). This sample of research activities that took place at the department of mechanical and industrial engineering in SQU is expected to have a large impact on the economic factor due to the direct link between this field of research and the industry. Therefore eight questions in the survey were used to evaluate this impact (four of which were directed to measure only the economic impact and the other four were related to economic impact together with societal and knowledge impact). The results surprisingly indicate that nearly 59% of the research carried, at the department of mechanical and industrial engineering, has no partnership or collaboration at any level with industry (whether locally or internationally and at both governmental and private sector levels). The other 40% were distributed as; 9% collaborated with local governmental bodies, 17% with the local private sector, and 15% with international bodies. The previous result was also supported by the results of other questions that look at how the research problem/objectives were formulated. Results show that 52% of the research carried was originated from research literature without reference to specific industrial problem or issue that faces industry inside or outside Oman. The remaining 48% percent were originated from local industrial issues inside Oman (30%) and outside Oman (18%). Even though the collaboration between industry and university research is not strong, 57% of the researchers believe that their results can be applied to solve specific existing engineering problems inside and outside Oman. Regarding the overall usefulness of the research carried for local and international industry, 65% of the researchers believe that their results and findings can be shared immediately with local and international industry.

These results were again emphasized by the fact that nearly 60% of the researchers think that their findings can lead to direct industrial investment and the setting of new regulations and policies for the industry. Not only has this, but 8% of the researchers thought that their results can be patented. The economic impact was also directly self-assessed by the researchers to rate their findings to the economic competitiveness in Oman and internationally, and the average rate was about 7 out of 10 (70%) which means a high contribution to economic impact.

5.2 Societal impact

Societal impact is to measure the direct benefits to societal issues (e.g. policy making, increasing public awareness, transfer of knowledge to society, etc.) (Bornmann 2017). We said direct benefit here to avoid other economic or knowledge impacts which will inevitably affect the society and it is not easy to separate societal impacts from other impacts. If we don't make this distinction, the societal impact will be just a consequence of high economic impact research. Also, we have to bear in mind that the societal impact of engineering research is not easy to assess like in social or medical research. Based on the literature, researchers have developed tens of indicators to evaluate societal impact but some of these evaluations require lots of effort and have to be justified in terms of the cost of the evaluation. One good indicator, which is also not costly, is the self (author) evaluation of his research impact on society and it has become part of the fund application to ask potential researchers about the societal impact of their research. In all, there is no standardized method of evaluating societal impact (Bornmann, 2017; Martin, 2011; Bornmann, 2012). In this work, this impact will be evaluated based on knowledge transfer and the level of communicating the research results with the general public and also based on the author feeling towards his research contribution to society.

The societal impact was assessed by looking at the effect of the research findings on the local community in general. The results show that researchers think that 58% of their research outcomes can be shared with the public. Only 6% of the researchers carried out their research particularly to increase social/public awareness about specific related issues. Despite that 58% of researchers' outcomes can be shared with the public, only 2% of the research outcomes were communicated with the general public through media (e.g. TV, newspapers, ...etc.). But the good news is, this societal impact was not completely lost because 58% of the researched topics have a direct relation with the course/s taught to SQU students by the researchers themselves. The societal impact was also directly self-assessed by the researchers to rate the societal impact of their research results, and the average rate was about 6.5 out of 10 (65%) which means a high contribution to societal impact. This average is considered very high especially for mechanical/industrial engineering research. This might be a result of the difficulty to distinguish between economic impact and societal impact. From the economic evaluation part, 65% of the researchers believe that their results and findings can be shared immediately with the local and international industry. This indicates that researchers might have considered any economic benefit will lead finally to a societal impact.

5.3 Knowledge impact

It is agreed that one of the important impacts of research is the development of new knowledge. The most common method used to evaluate this criterion is by measuring the scientific impact of the research (e.g. counting the number of citations by other researchers). This commonly used method faces a lot of criticism such as; effect of uncited work [PLoS Medicine Editors 2006, Todd and Ladle 2008, and Abbott et al.2010), multiple publications of high impact work (Todd and Ladle 2008), published in national journals (Abbott et al.2010), excessive citation of an author's own work[22], forming 'citation coalitions'(Abbott et al.2010), poor citation practices (Abbott et al.2010), and publication language restrictions (Raan et al., 2011). To evaluate knowledge impact, the author has calculated the average research impact for all papers published in journals by calculating the number of a citation for each journal paper from Google Scholar. Then the number of a citation for all journal papers was divided by the number of research articles. This gives an average impact of 2.3. Researchers' self-assessment of the knowledge impact was also found to be high with an average of 7.5 out of 10 (75%) which means a high contribution to knowledge impact. On the other hand, researchers think that 46% of their work will contribute to the stock of knowledge in the field and they are not only useful for the specific problem they were carried to solve. Knowledge impact of research (e.g. high number of citations and/or research is published in reputed scientific journals) does not

necessarily indicate its societal and/or economic impact. This can be noticed from the high knowledge impact findings compared to the socioeconomic impacts for the same researches.

6. Validating results

RAND Europe is an institute based in the United Kingdom which has more than 1800 staff in 50 countries, with a vision to help policymakers make decisions that are based on the best available information through research and analysis. RAND Europe was asked to design and apply a research impact performance management system that demonstrates and communicates the impact of The Research Council's programs in Oman concerning TRC's mandate. RAND Europe produced a final report in 2015 which includes measures for the performance of the research funded which was mainly based on bibliometrics, an Impact Finder survey, and case studies. As far as the author's knowledge, this is the only report in which clear measures and indicators were developed and applied to funded researches in Oman to evaluate research impact in Oman. Some of the relevant findings produced in that report were compared with the results reported in this work as shown in Table.1 (appendix). There is a good agreement between the two findings.

7. Conclusion

Good quality and highly cited research proved to be not a suitable measure for societal and economic impact. Meanwhile, getting accurate data for economic and societal impact might be very expensive and time-consuming. The focus of this paper is a significant subject that addresses a low-cost survey-based approach to evaluate engineering research. It discusses measurable indicators to evaluate the impact factors of engineering research on society, economy, and advancement of knowledge. This study used only twelve questions to get a quick but overall view of the research impact. These survey questions were extracted from commonly adopted indicators for research impact in literature. The survey results were validated against, tedious, and time-consuming, data collection approach and it showed good agreement. Although the results presented were realistic but repeating, this work might face a common weakness of any survey approach due to bias and/or ignorance of respondents. Finally, although gathering socioeconomic impact data is not an easy task but a simplified method (as the one adopted in this work) can be applied to give a good overview of the current situation provided that researchers answer questions objectively.

Acknowledgment

The author would like to thank all teaching staff at the department of mechanical and industrial engineering for their participation in the survey that led to this paper. Thanks go to Dr. Nabeel Al-Rawahi for revising the questionnaire draft. Finally, the author would like to express a special thanks to his father Dr. Abdalla Hassan Zarog for reading the draft paper, his useful discussion, and for the thoughtful and comprehensive comments I received from him.

References

Appendix:

Table.1 comparison between results from RAND Europe report and this work

Category	Question	RAND Europe	This work
knowledge impact	Citation	above the world average (>1) : good (based on MNCS[1])	1.3 : good (based on G.S[2])
knowledge impact	rate the scientific impact	above the world average (>1): good(based on MNCS[1])	7.5/10: very good
Societal impact	For the usefulness of your results for public,	20% influenced organizations' regulations, policies, and procedures or society welfare	29% Can lead to new regulations and policies
Societal impact	direct relation with the course/s you teach/taught	33% influenced teaching activities in further, or higher undergraduate education	42% influenced teaching courses
Economic impact	partnership/collaboration with industry, R&D or private sector	48% with no collaboration: high	59% with no collaboration: high
Economic impact	The research problem originated/ formulated from industry	46% has agreements with industry and governmental bodies	48% originated from industry

| Economic impact	Your particular research findings for the paper can lead to a patent	10% Research cited by patents or IP protected through copyright or trademark	8% can lead to a patent

1) **MNCS (mean normalized citation score) According to using Thomson Reuters: The average number of citations per article in a field relative to the world average (self-citations not included). Thomson**

2) **Average of Google scholar citation**

Table.2 Survey categories and questions

Question No.#	Category	Question
1	Societal impact	For the usefulness of your results for public, Have your results/findings been communicated with social media/TV/newspapers...etc 1. Yes (specify) ………… 2. Can be useful for public locally 3. Can be useful for public locally internationally 4. Not useful to share with the public
2	Societal impact	Is your researched topic has a direct relation with the course/s you teach/taught in SQU 1. No 2. Yes
3	Societal impact	How do you rate the societal impact of your research results (merely contribution to society) [10 is very high contribution] 1 2 3 4 5 6 7 8 9 10
4	Economic impact	Were there any partnership/collaboration with industry, R&D, or private sector? 1. No 2. with local gov. bodies 3. with the local private sector 4. with international sectors
5	Economic impact	The research problem originated/formulated from 1. Scientific literature 2. local industry 3. international industry 4. local society
6	Economic impact	How do you rate the economic impact of your research results on Oman(merely contribution to economic competitiveness to Oman) [10 is highest] 1 2 3 4 5 6 7 8 9 10
7	Economic impact	How do you rate the economic impact of your research results at international level (merely contribution to economic competitiveness internationally) [10 is very high contribution] 1 2 3 4 5 6 7 8 9 10
8	Economic/societal impact	What is the main aim of the publication? 1.1 Increase knowledge in the field 1.2 apply knowledge for a specific problem in Oman 1.3 Increase social/public awareness 1.4 apply knowledge for specific engineering problem
9	Economic/ knowledge impact	How would you describe your main research areas : 1. Increase the stock of knowledge 2. Related to local specific problems 3. Related to international specific problems 4. Related to pure science

10	Economic/societal impact	Your particular research findings for the paper can lead to 1. Patent 2. private sector investment 3. new regulations/policies 4. None
11	Economic/societal impact	Do you think that your results can be shared immediately with industry/policymakers? 1. No 2. Yes, locally(specify) ………… 3. Yes, internationally (specify)…….
12	knowledge impact	How do you rate the scientific impact of your research results (merely contribution to knowledge) [10 is very high contribution] 1 2 3 4 5 6 7 8 9 10

Figure.1: Possible pathways to impact (Denicolo 2014).
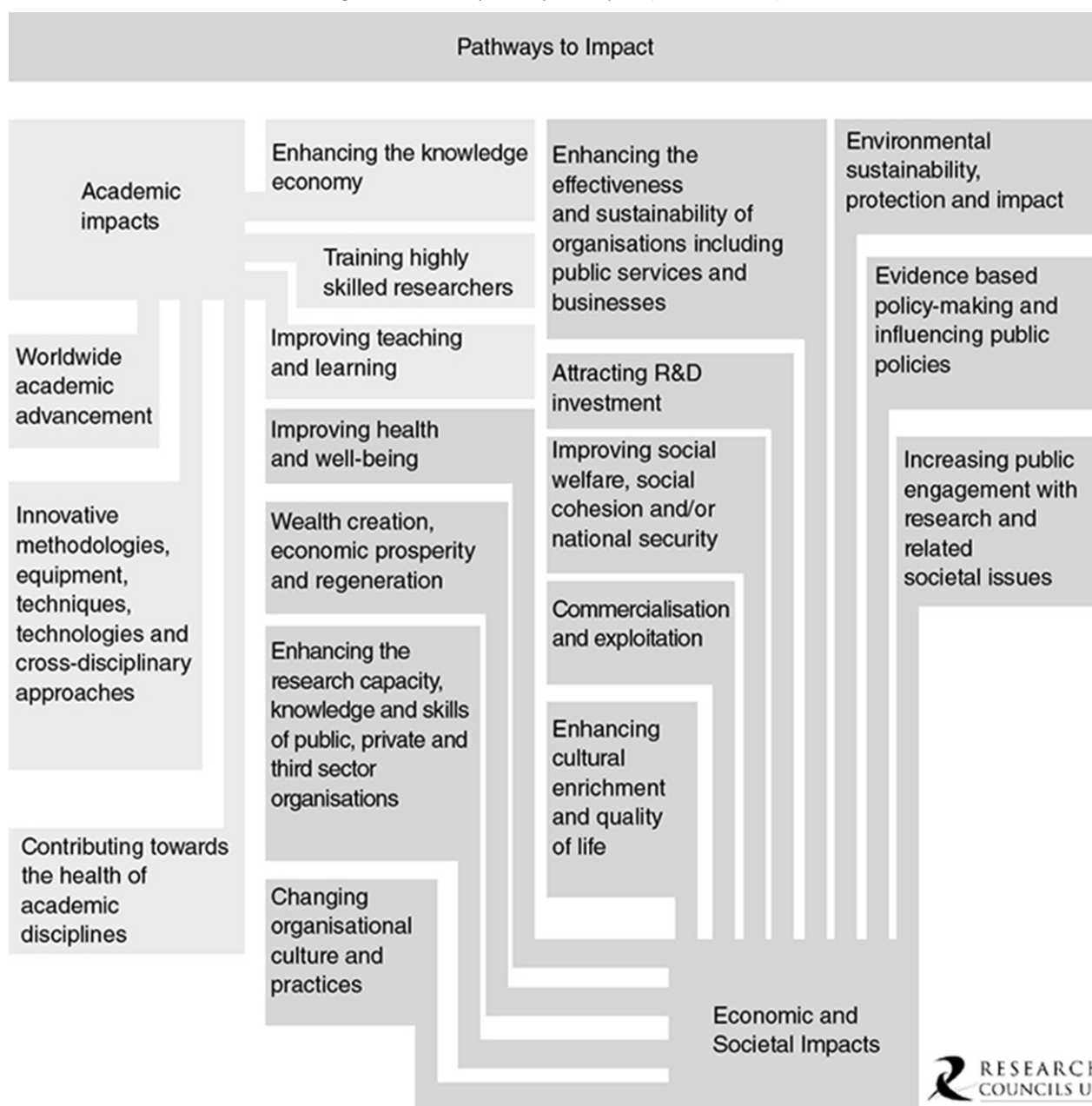
Abbott A, Cyranoski D, Jones N, Maher B , Schiermeier Q, Noorden RV (2010), Metrics: Do metrics matter?. Nature, 465(7300:860–862).

Anon. (2006), The Impact Factor Game. PLoS Medicine, 3(6).

Anon. (2011), National Science Foundation: Where Discoveries Begin. NSF, Available at: https://www.nsf.gov/bfa/dias/policy/meritreview/ [Accessed January 20, 2019].

Anon. (2013), Faculty Mentored Undergraduate Research Award Program (FURAP). HOME | The Research Council, Available at https://www.trc.gov.om/trcweb [Accessed January 20, 2019].

Anon. (2014), Open research grant guidelines, The Research Council, Available at https://www.trc.gov.om/trcweb [Accessed March 14, 2019].

Anon. (2018), Call for smart city proposals, Smart City Platform, The Research Council, Available at https://www.trc.gov.om/trcweb [Accessed March 14, 2019].

Anon. (2018), Government expenditure on science, engineering, and technology, UK: 2016. Office for National Statistics, Available at https://www.ons.gov.uk/economy/governmentpublicsectorandtaxes/researchanddevelopmentexpenditure/bulletins/penditureonscienceengineeringandtechnology/2016 [Accessed January 20, 2019].

Anon., Approved Furap Project, Available at https://www.squ.edu.om/dor/TRC-Advertisment [Accessed March 14, 2019].

Anon., Deanship of Research, SQU Portal, Available at http://www.squ.edu.om/dor [Accessed January 20, 2019].

Anon., National Science Foundation-Where Discoveries Begin, NSF, Available at https://www.nsf.gov/about [Accessed January 20, 2019].

Anon., Preparing new proposals to include national importance. Preparing new proposals to include National Importance - EPSRC website. Available at: https://epsrc.ukri.org/funding/applicationprocess/preparing/includingnationalimportance [Accessed January 20, 2019].

Anon., Renewable Energy Strategic Research Program, The Research Council. Available at: https://www.trc.gov.om/trcweb [Accessed January 20, 2019].

Bornmann L (2012), Measuring the societal impact of research. EMBO reports 13(8:673–676).

Bornmann L (2012), What is the social impact of research and how can it be assessed? a literature survey. Journal of the American Society for Information Science and Technology, 64(2:217–233).

Bornmann L (2016), Measuring impact in research evaluations: a thorough discussion of methods for, effects of, and problems with impact measurements. Higher Education, 73(5:775–787).

Denicolo P (2014), Success in Research: Achieving Impact in Research. SAGE Publications Ltd. Available at https://uk.sagepub.com/en-gb/eur/achieving-impact-in-research/book240291 [Accessed January 20, 2019].

Drucker J and Goldstein H (2007), Assessing the Regional Economic Development Impacts of Universities: A Review of Current Approaches. International Regional Science Review, 30(1:20–46).

Krapels J, Jones MM, Castle-Clarke S, Kryl D, Younossi O. (2015), Developing a research impact performance management system for The Research Council, Oman: Final Report.

Mapp, EPSRC Impact Report 2016-2017. MAPP. Available at: https://mapp.ac.uk/news/epsrc-impact-report-2016-2017 [Accessed January 20, 2019].

Martin BR (2011), The Research Excellence Framework, and the impact agenda: are we creating a Frankenstein monster?. Research Evaluation, 20(3:247–254).

Penfield T, Baker MJ, Scoble R, Wykes, MC (2014), Assessment, evaluations, and definitions of research impact: A review. Research Evaluation, 23(1:21–32).

Raan TV, Leeuwen T, Visser M (2011), Non-English papers decrease rankings. Nature, 469(7328:34–34).

Reid G, Why Should the Taxpayer Fund Science and Research?. NCUB, Available at: http://www.ncub.co.uk/reports/why-science.html [Accessed January 20, 2019].

Roessner D, Manrique L, Park J (2010), The economic impact of engineering research centers: preliminary results of a pilot study. The Journal of Technology Transfer, 35(5:475–493).

Rosemberg C, Simmonds P, Potau X, Farla K, Sharp T, Wain M, Cassagneau-Francis O, Kovacs K (2015), Assessing the economic returns of engineering research, available at https://www.raeng.org.uk/publications/reports/assessing-the-economic-returns-of-engineering-rese [Accessed January 20,

2019].

Todd PA, Ladle RJ (2008), Citations: poor practices by authors reduce their value. Nature, 451(7176:244–244)

Zarog M (2019), In Achieving the Most of Limited Research Budget for Engineering Research Projects: A Case Study at SQU", Journal of Engineering Research (TJER), 16(2)

Stutely, R. (2002). The Definitive Business Plan, London: Financial Times Prentice Hall.

Unus, I. (2005). The story of Musa and Harun: Lesson in leadership, International Institute of Islamic Thoughts, Herndon. Retrieved July 18, 2016 from:

www.islamist.org

White R (2008). Three characteristic of leadership competence, consistency and character.

Woods, A. & Joyce, P. (2003). Owner-Managers and the Practice of Strategic Management: International small Business Journal, 21(2), 181-195.