Understanding the Societal Impact of Academic Research

Acknowledgements

This project is a collaboration between Impact Institute and Singapore Management University (SMU), with the two parties co-owning the IP rights.

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Table of Contents

Executive Summary

Return to contents page

Context: Recognising the significant role academic research plays in advancing Singaporean society, the Singapore Green Finance Centre (SGFC) aims to understand and demonstrate the societal impact of such research. In this report, SGFC and Impact Institute evaluate how academic research influences economic development and informs public policy, providing a foundation for enhancing its contribution to societal progress.

Method: This report systematically analysed various impact frameworks to link academic research with specific societal outcomes. By integrating these frameworks, tailored impact pathways that connect research outputs to measurable economic and policy impacts were developed, and used to assess how effectively research influences public policy and fosters economic growth.

Throughout the analysis, a hypothetical research institute was employed to illustrate how research organizations can generate societal impact. Since the research team is based at Singapore Management University (SMU), the Singaporean context was used, drawing on local economic data and policy environments. This approach demonstrates how these frameworks can be applied in real-world settings and adapted elsewhere. Conclusions and limitations are presented for each impact pathway, highlighting how research translates into societal benefits and where measurement challenges remain.

Results: The report offers an initial framework for monitoring and enhancing research contributions to society, identifying key impact pathways and relevant data points that illustrate how academic research can translate into economic and policy benefits. The findings underscore the potential for research to shape public policy and drive economic change, serving as a starting point for quantifying and valuing research impact.

Limitations: The study highlights several challenges, including the difficulty of quantifying research impact beyond GDP measures, the complexity of linking research to economic growth, and the lack of empirical data on the causal relationship between research and policy impact.

Introduction

Introduction

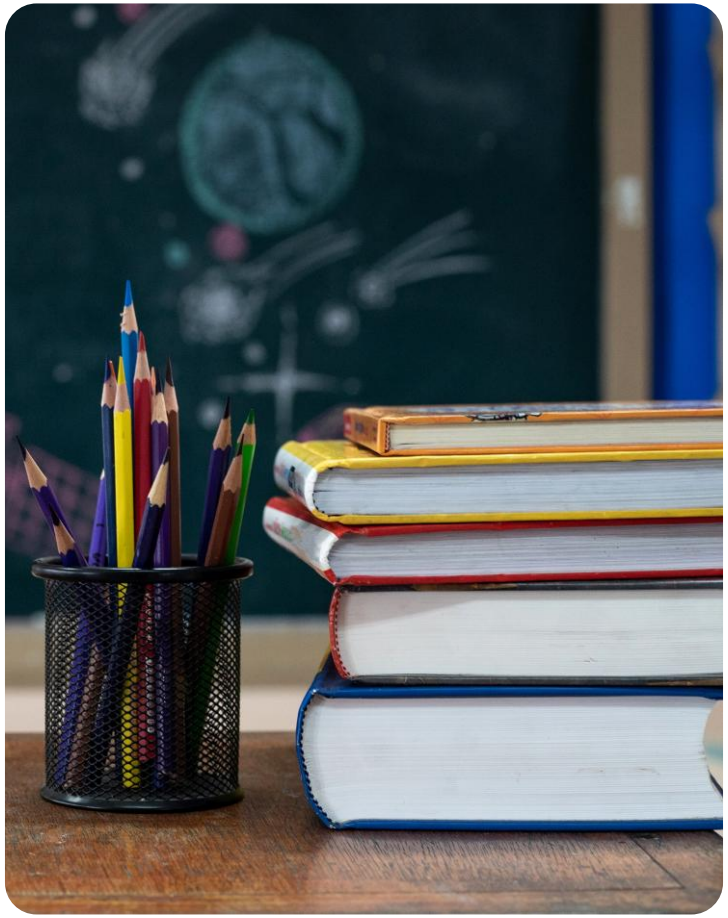
Return to contents page

In an increasingly interconnected and dynamic world, the impact of research extends beyond academic discourse to profoundly shape economic development and social policy. For universities and research institutes, the ability to illustrate and harness the societal impact of their research is paramount. This report analyses how academic research influences society. Academic research is critical in understanding complex social phenomena, addressing societal issues, and informing public policy. From examining social behaviour and cultural dynamics to evaluating public policies and economic strategies, the findings of this research have the potential to drive significant positive change.

This report explores how academic research impacts society by evaluating real-world applications and contributions. It shows how research findings influence economic, policy, and social interactions to create broader value for society, thereby demonstrating how research institutes play a significant role in societal development. Furthermore, the framework presented here provides a starting point for future research to quantify and value the indirect effects of academic research, enabling a deeper understanding of its full impact across various societal domains.

In addition, through impact assessments, the report provides a framework for understanding and enhancing the role of research institutes in addressing societal challenges and advancing social progress. The methodology entailed analysing different frameworks for measuring impact, reviewing existing models from global institutions, assessing their applicability to the university's context, and developing tailored strategies to capture and communicate the societal benefits of research.

By examining these frameworks, the report aims to provide robust tools for evaluating research impact, ensuring that research institutes can continuously monitor and articulate their contributions to societal development, and guide their efforts in maximising research impact. As research institutes embark on their strategic journey, they seek to underscore their commitment to generating knowledge that advances academic understanding and drives meaningful and sustainable change.



Introduction: Objectives

Return to contents page

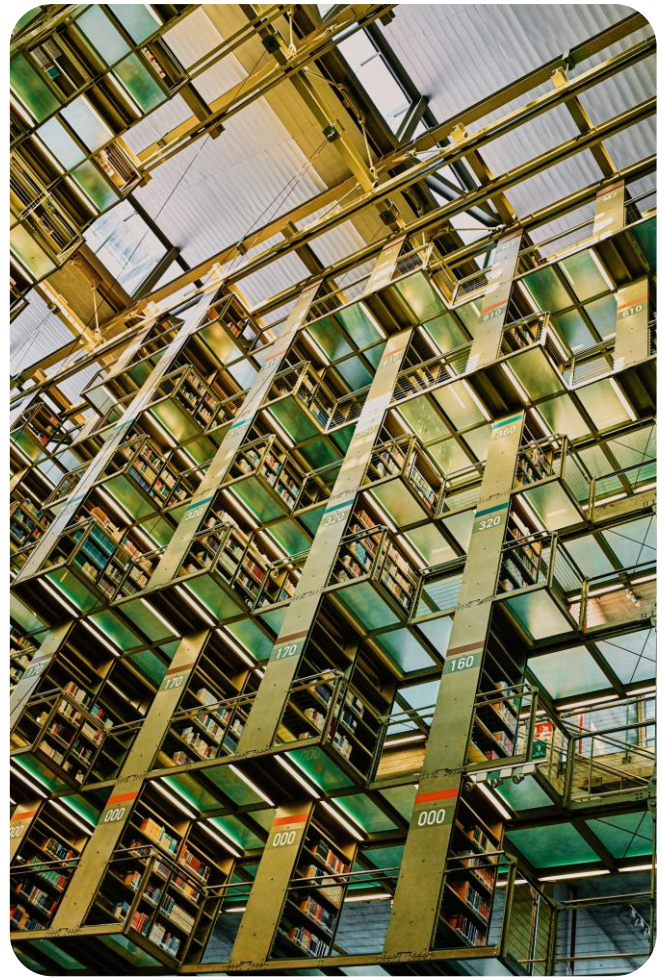
This report aims to develop a comprehensive framework to map the pathways through which academic research translates into societal impact. The report illustrates how research drives societal change and identifies key metrics and data points for monitoring and analysing this impact. A key component of this project is the integration of a proof of concept, demonstrating the feasibility of capturing and mapping these impacts. Through this, the report seeks to provide a foundational framework to guide impact strategy and measurement efforts, facilitating a more extensive data collection process and clearly linking academic research to its societal contributions. To achieve this, the report focuses on the following sub-objectives:

1. **Research and Review Existing Frameworks:** Conduct a thorough examination of current research impact frameworks to identify best practices and methodologies.

2. **Integrate Relevant Frameworks:** Adapt and incorporate the most pertinent frameworks to develop key impact pathways

3. **Fill in Impact Pathways:** Identify data sources that could populate these impact pathways, ensuring they accurately reflect the contribution of research to societal impact. Here the research utilises local Singaporean economic data to provide a practical showcase of how the research institute impacts society

4. **Evaluating Opportunities and Limitations:** Assess the potential for quantifying impact based on available data, identifying gaps and limitations in calculating research impact.




The Impact of Academic Research

Overview

Return to contents page

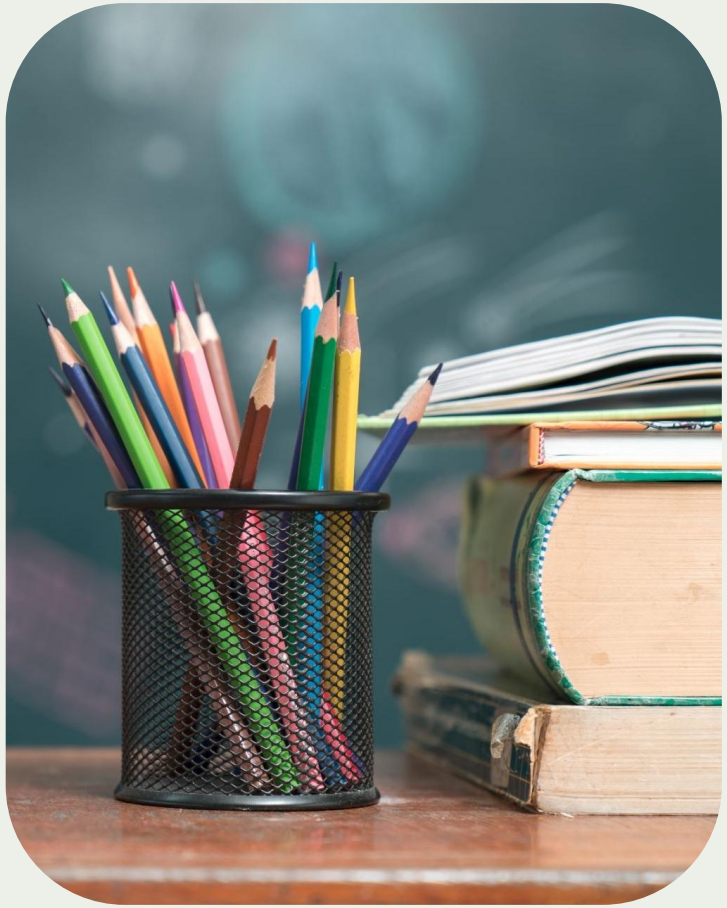
To understand the multifaceted impact of academic research, a comprehensive list of impact pathways across six capital dimensions was developed by applying relevant research frameworks and utilising available data and inputs.

The first stage of the impact pathways encompasses the research and knowledge generated, as evidenced by the publication of scientific articles, books, and other scholarly outputs. In this initial phase, the increased production of outputs suggests an increased generation of knowledge and, consequently, a potential rise in the research institute's overall impact.

The impact of research is highly indirect; producing research outputs alone does not directly result in impact. Instead, the true impact of research depends largely on how knowledge is applied and transferred beyond the academic sphere. To capture this indirect relationship, a nested impact pathway was developed, in which two activities are mapped.

The divergence of these pathways occurs at the second stage. By applying the concept of "productive interactions," it becomes possible to examine how the institute engages with external stakeholders to transfer and apply research-generated knowledge. According to the SIAMPI framework, this mechanism enables a university to augment its overall impact.

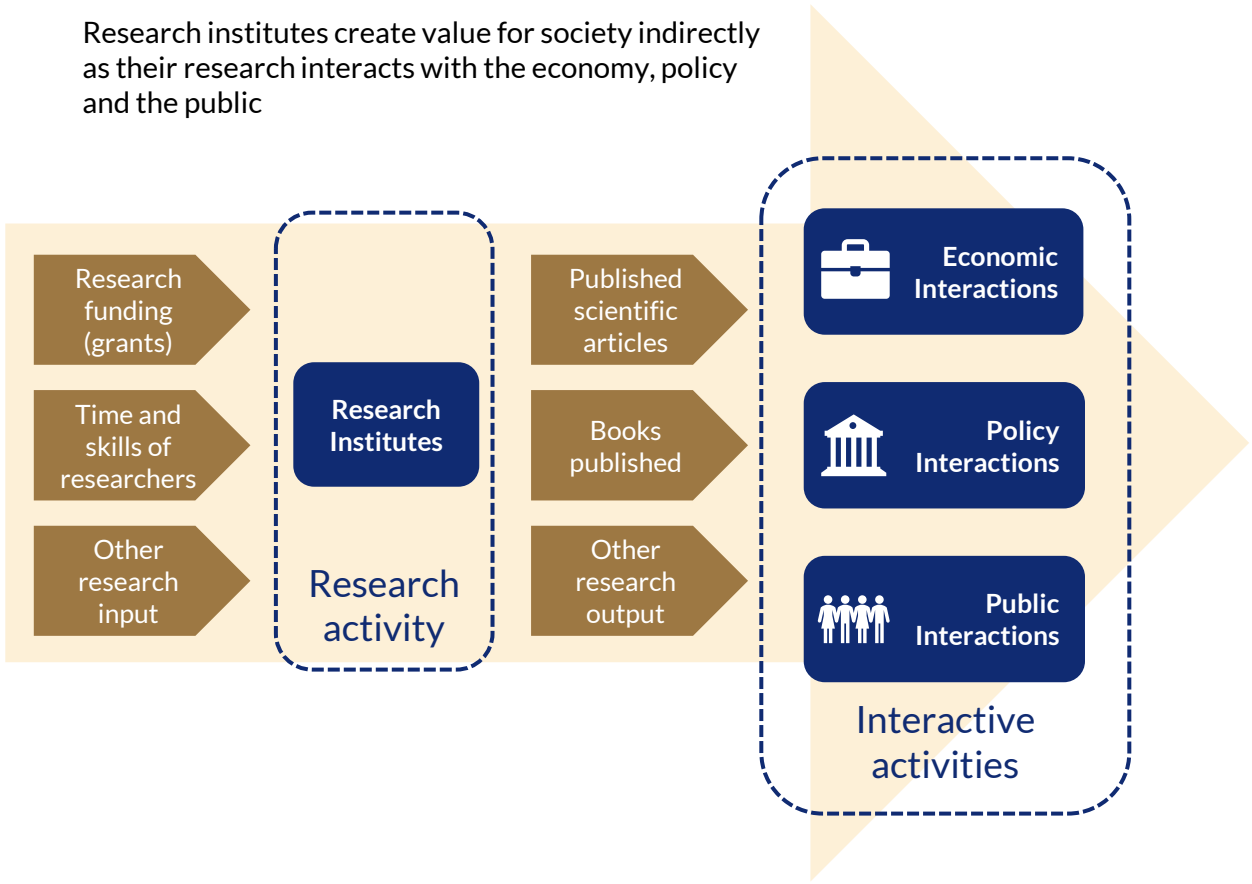
Due to data limitations, a precise quantification of each individual impact was not feasible. However, the commercial and policy engagement pathways emerged as the most promising and are explored in greater detail in the following sections. Additionally, the scarcity of research on public and social interactions prevented a deeper analysis in this area.



The Impact of Academic Research

Return to contents page

Research institutes create value for society indirectly as their research interacts with the economy, policy and the public



Outcomes

- Job creation
- Increased productivity and efficiency
- Contributing to innovation and entrepreneurial activity

- Improved goods and services

- Educational quality
- Accessibility of data
- Strengthened cyber security

- The quality, accessibility and/or cost-effectiveness of a public service has been improved
- Improved functioning of institutions

- Improved heath outcomes
- Improved knowledge, education, training and skills of current and future populations

- Reduced pollution/GHG emissions
- Improved management of environmental risk
- Increased public awareness

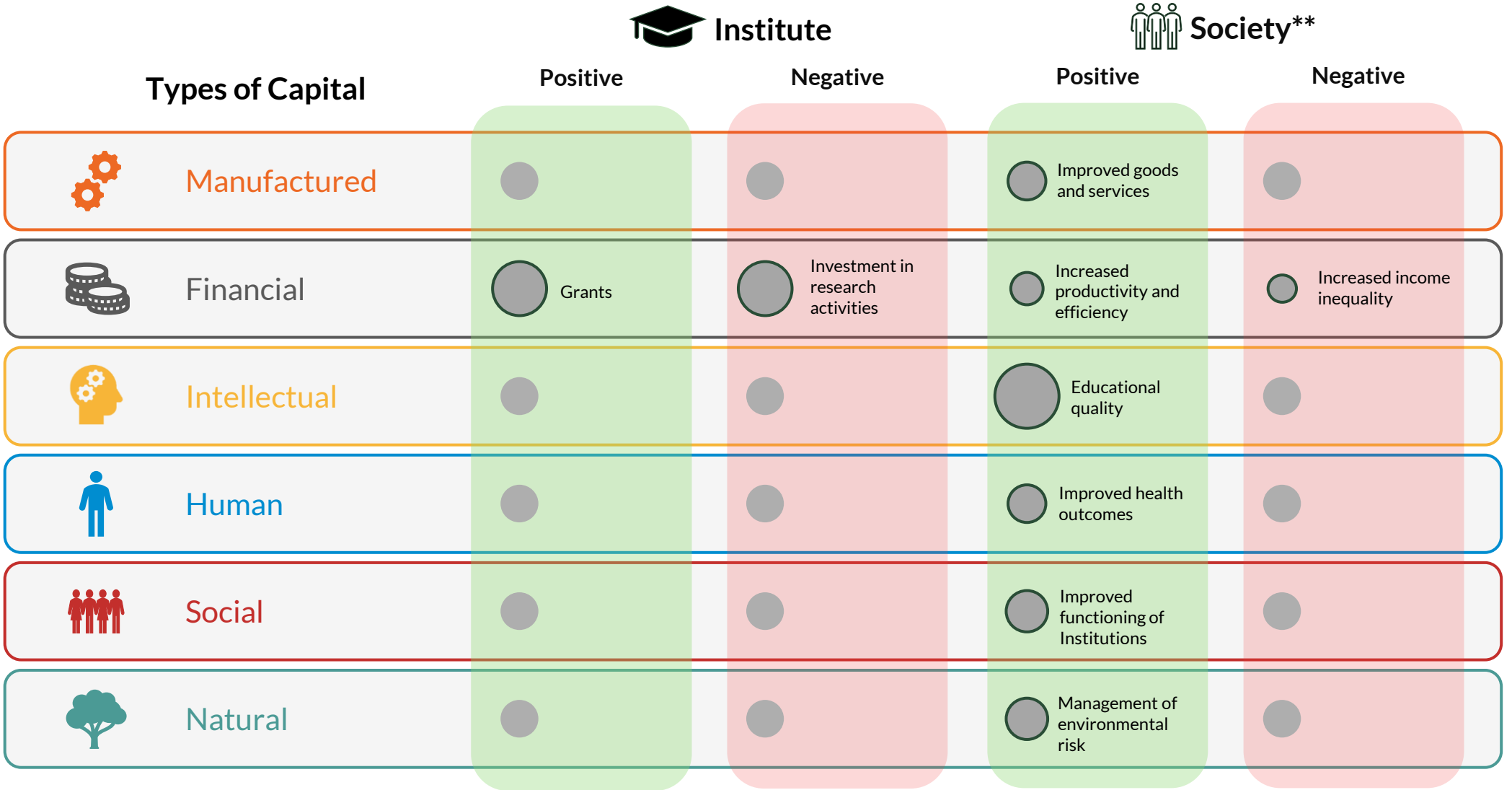
Impact on Society*

- Financial capital
- Manufactured capital
- Intellectual capital
- Social capital
- Human capital
- Natural capital

* The definitions for the six capitals are taken from the Value Reporting Foundation.

Illustrative overview of the impact of a research institution*

Return to contents page



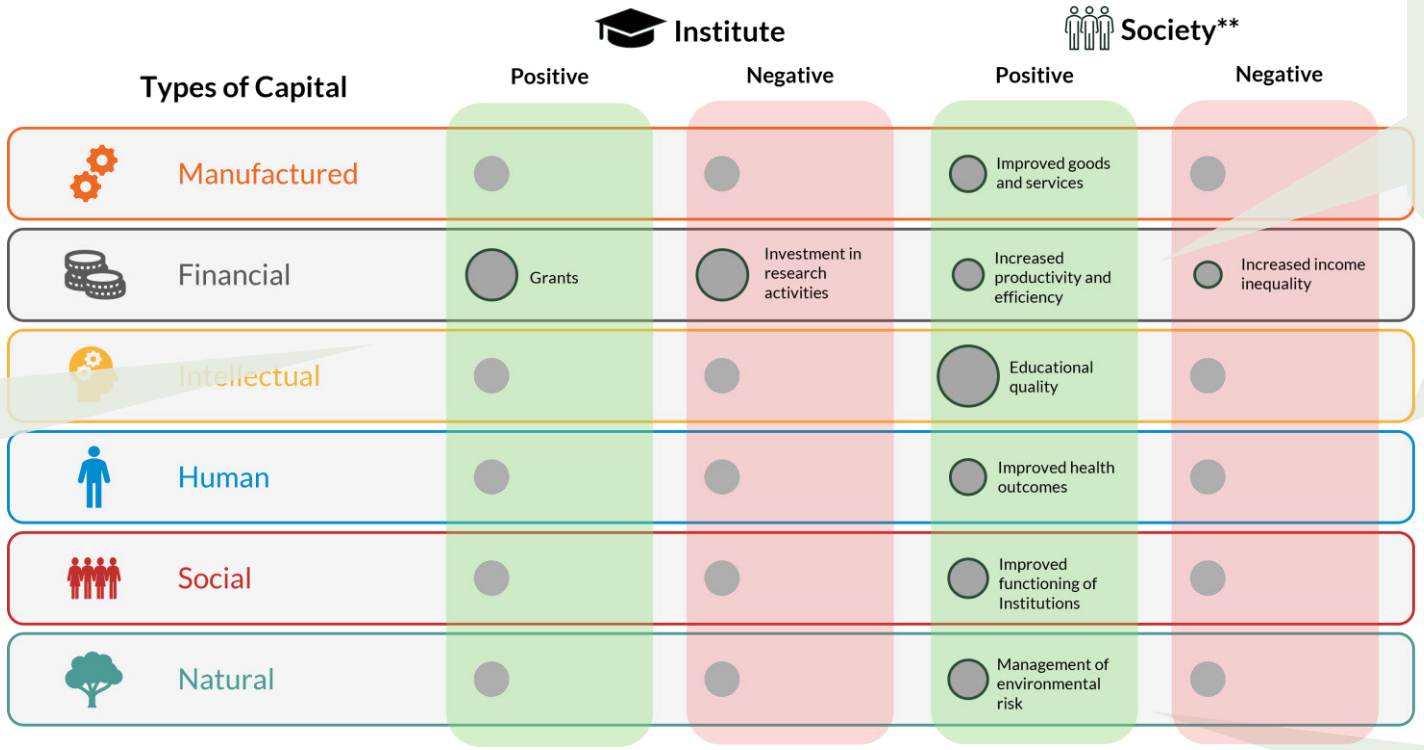
*These visual representations provide a general indication of relative impact or importance, but should not be interpreted as exact quantitative measurements

** Stakeholder groups can be further specified to include for example employees, citizens, local communities, etc.

Illustrative overview of the impact of a research institution*

Return to contents page

Institutes receive grant money which is a positive inflow on financial capital. With that they invest in research activities.



Research has the indirect positive effect on the economy as business use research findings to improve productivity and efficiency (boosting GDP and creating jobs) and by improving the value of the goods being produced.

Applications of research can lead to unintended consequences. For example, innovations stemming from research may drive GDP growth but inadvertently exacerbate income inequality.

Research indirectly contributes to human social and environmental capital but helping to inform improved policy

*These visual representations provide a general indication of relative impact or importance, but should not be interpreted as exact quantitative measurements

** Stakeholder groups can be further specified to include for example employees, citizens, local communities, etc.

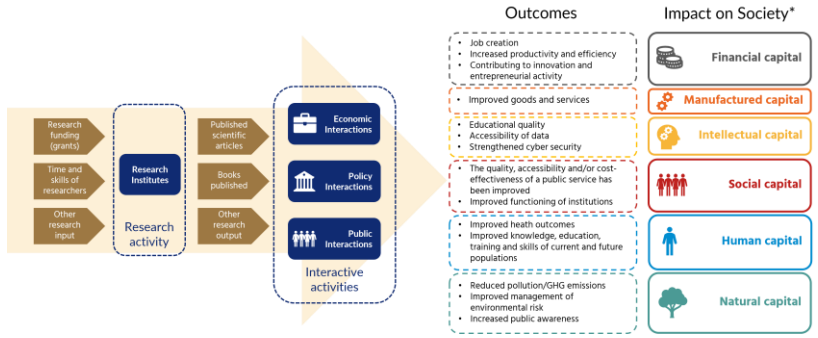
The Impact of Academic Research

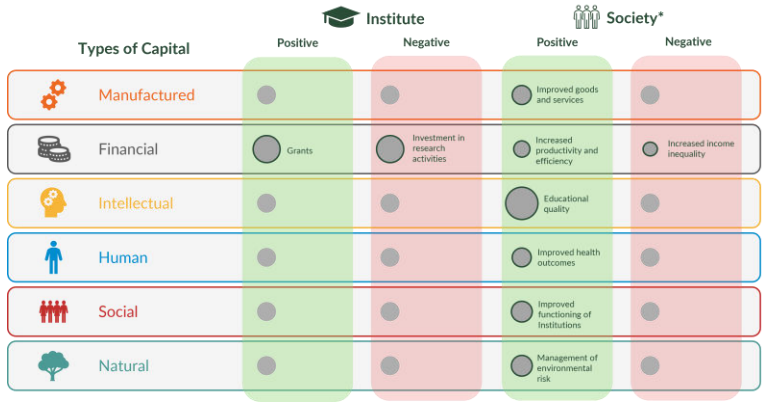
Return to contents page

The preceding pages effectively showcase how a research institute generates a positive impact across six distinct capital dimensions through its research initiatives. The first diagram illustrates the collaborative contributions of various researchers, alongside the investment of time and resources, which culminate in the publication of scholarly outputs, including books and scientific articles. However, the successful transfer and application of this knowledge are heavily reliant on the institute's engagement with relevant stakeholders across economic, policy, and public domains. This strategic interaction facilitates the effective dissemination and utilisation of research findings, enabling the institute to indirectly influence the various capital dimensions. The diagram further identifies several indicators that provide compelling evidence of how research institute can contribute to these capitals. For instance, by enhancing the efficiency of goods and services in society through its research, research institute may significantly contribute to the growth of manufactured capital.

The second diagram recognises the dual potential for both positive and negative impacts arising from research activities. Whilst the research output itself may be inherently neutral; its application can lead to unintended consequences. For example, innovations stemming from academic research may drive GDP growth but inadvertently exacerbate income inequality. It is therefore important to consider negative impact into the assessment.

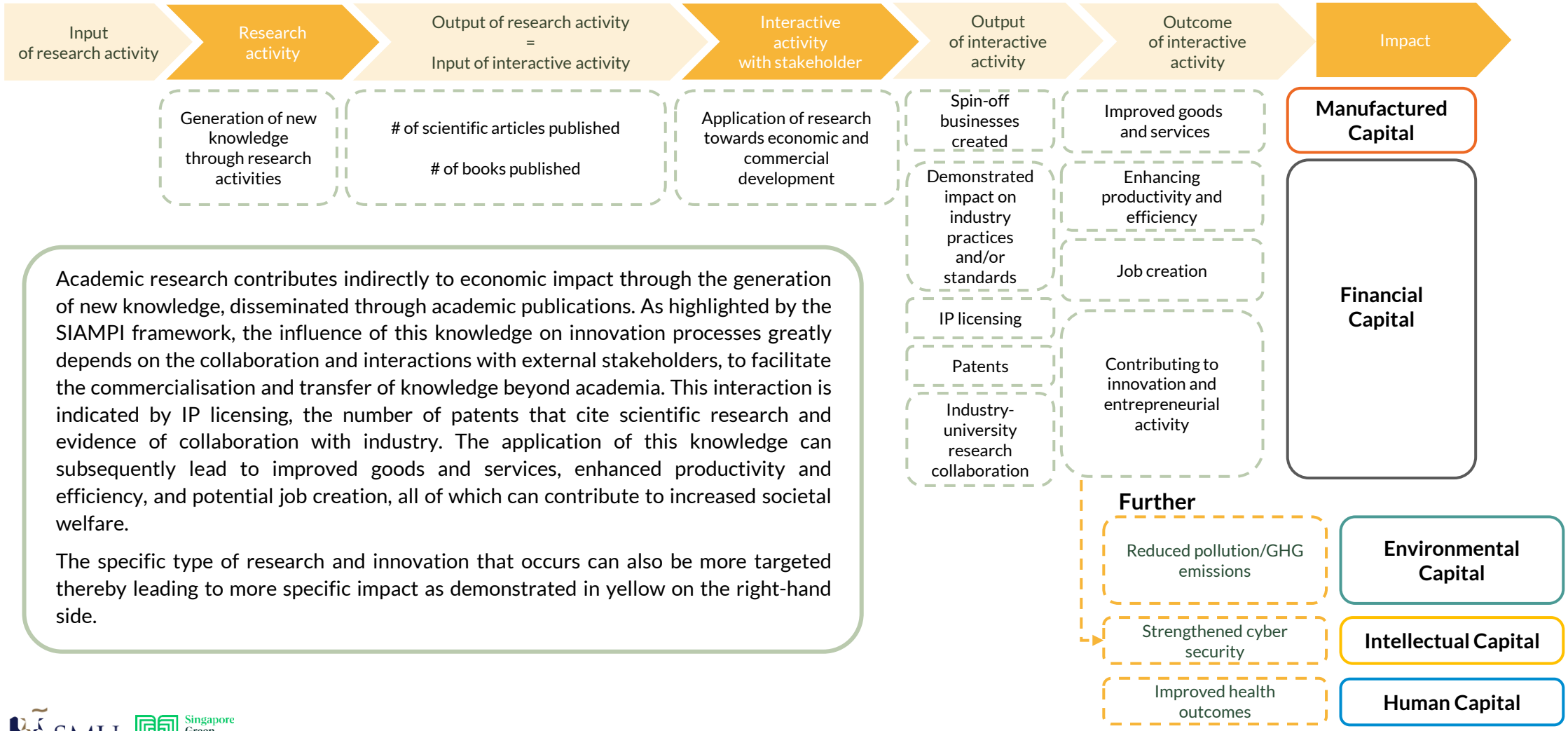
Additionally, the second diagram highlights that the impact of academic research can vary significantly based on stakeholder perspectives, whether it relates to the institute itself or the wider societal context. Assessing impact from the stakeholder viewpoint is therefore crucial, as a positive outcome for one stakeholder may result in negative repercussions for another.





Economic Interactions

Return to contents page

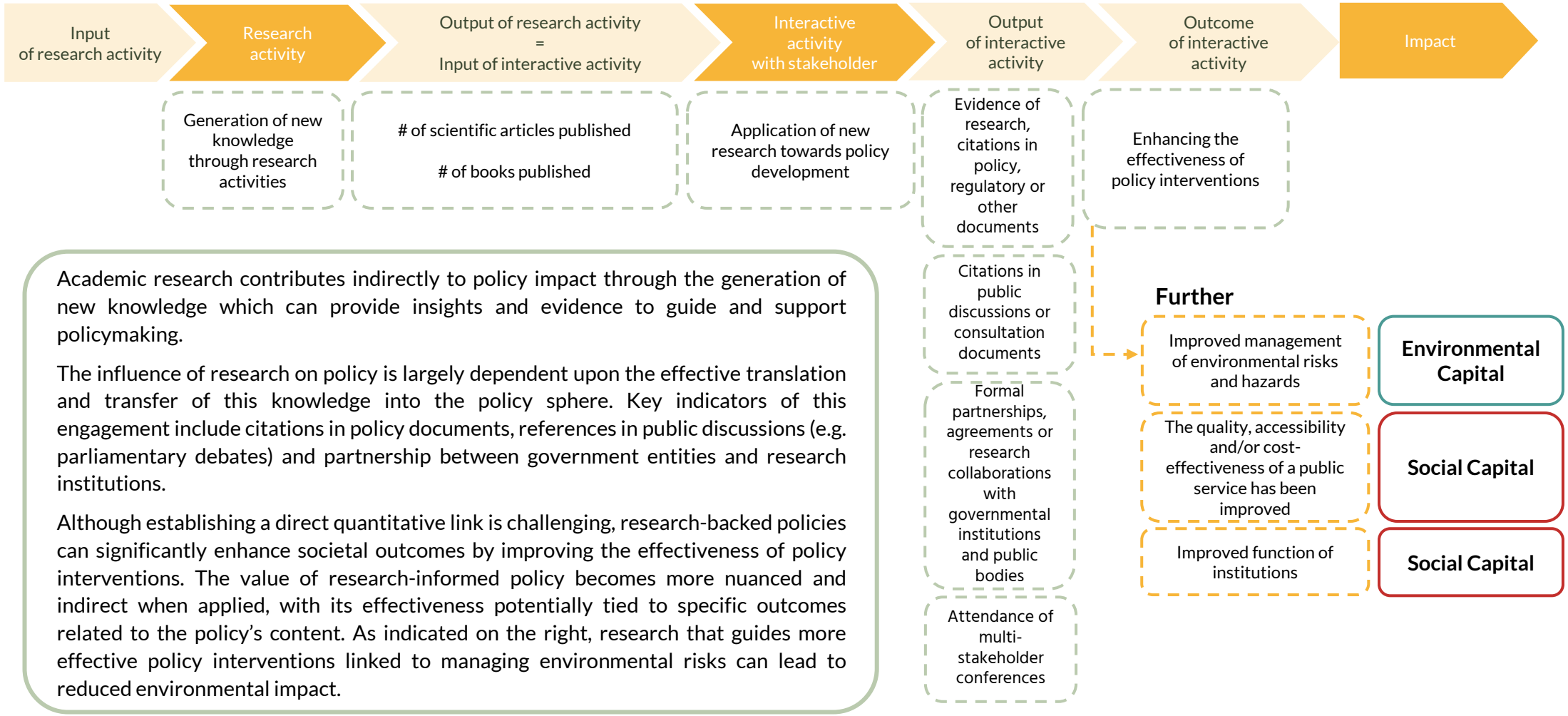


Academic research contributes indirectly to economic impact through the generation of new knowledge, disseminated through academic publications. As highlighted by the SIAMPI framework, the influence of this knowledge on innovation processes greatly depends on the collaboration and interactions with external stakeholders, to facilitate the commercialisation and transfer of knowledge beyond academia. This interaction is indicated by IP licensing, the number of patents that cite scientific research and evidence of collaboration with industry. The application of this knowledge can subsequently lead to improved goods and services, enhanced productivity and efficiency, and potential job creation, all of which can contribute to increased societal welfare.

The specific type of research and innovation that occurs can also be more targeted thereby leading to more specific impact as demonstrated in yellow on the right-hand side.

Policy Interactions

Return to contents page



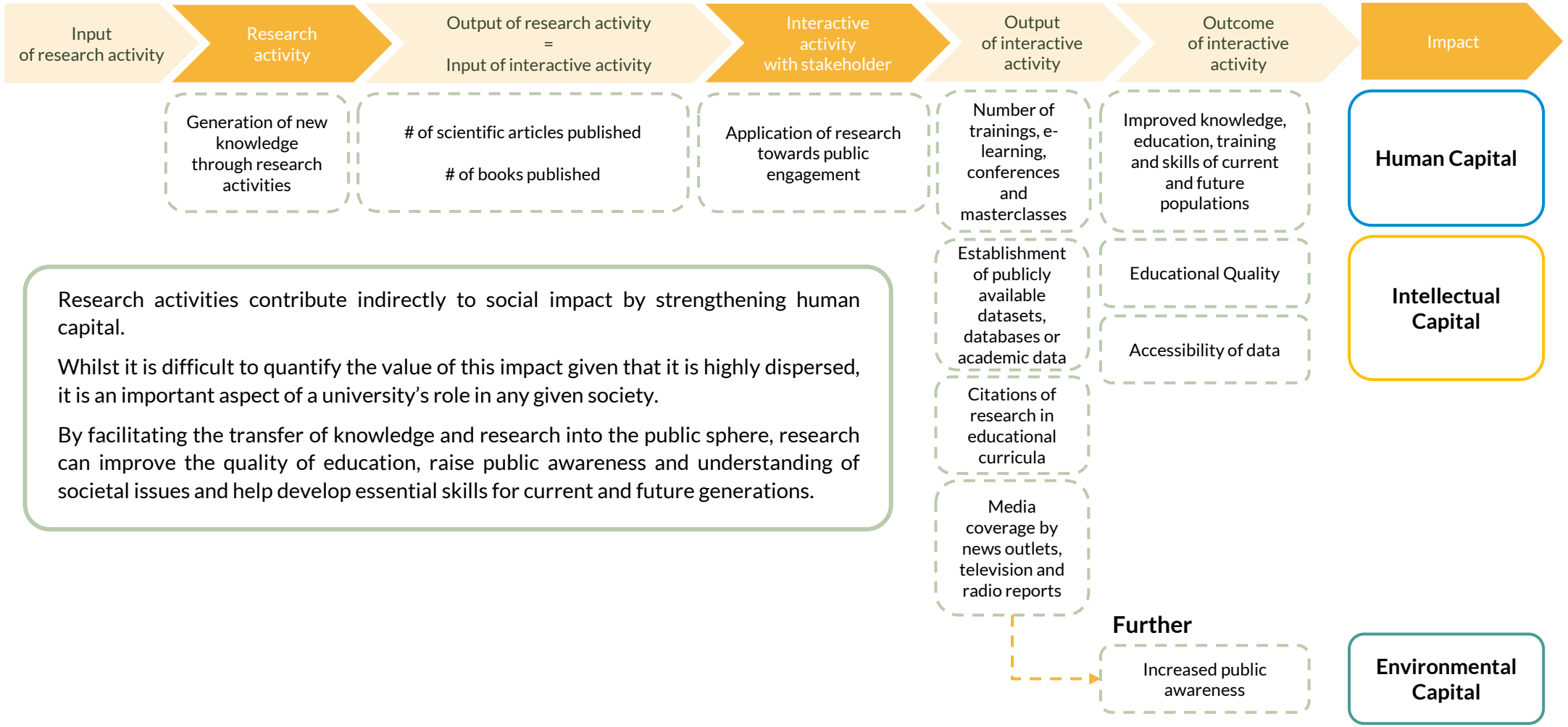
Academic research contributes indirectly to policy impact through the generation of new knowledge which can provide insights and evidence to guide and support policymaking.

The influence of research on policy is largely dependent upon the effective translation and transfer of this knowledge into the policy sphere. Key indicators of this engagement include citations in policy documents, references in public discussions (e.g. parliamentary debates) and partnership between government entities and research institutions.

Although establishing a direct quantitative link is challenging, research-backed policies can significantly enhance societal outcomes by improving the effectiveness of policy interventions. The value of research-informed policy becomes more nuanced and indirect when applied, with its effectiveness potentially tied to specific outcomes related to the policy's content. As indicated on the right, research that guides more effective policy interventions linked to managing environmental risks can lead to reduced environmental impact.

Public Interactions

Return to contents page



Research activities contribute indirectly to social impact by strengthening human capital.

Whilst it is difficult to quantify the value of this impact given that it is highly dispersed, it is an important aspect of a university's role in any given society.

By facilitating the transfer of knowledge and research into the public sphere, research can improve the quality of education, raise public awareness and understanding of societal issues and help develop essential skills for current and future generations.

Frameworks Review

Overview

Return to contents page

Several frameworks have been developed to systematically assess and demonstrate the societal impact of research. They provide standardised measures and indicators to track and communicate the impact of research activities to relevant stakeholders. Their primary objectives include maximising returns on investment by ensuring that research yields tangible benefits for society, standardising impact measurement to facilitate comparisons across projects and time, and guiding research strategy to align activities with societal needs.

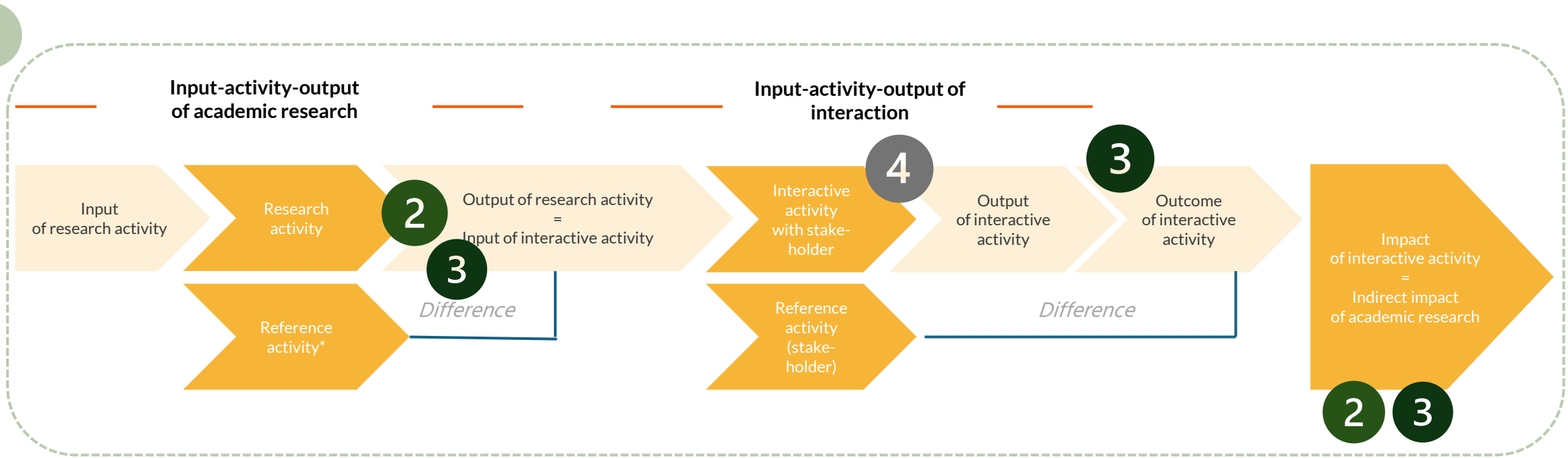
Each framework provides a unique perspective on how research translates into societal impact, utilising different indicators and metrics. A comprehensive review was conducted to evaluate their relevance to the Impact Weighted Accounts Framework (IWAF) for impact measurement. The IWAF is a framework that facilitates businesses and investors to measure their social, human and environmental impacts and expresses them in monetarily valued units. It was developed by the Impact Economy Foundation (IEF) together with partners Harvard Business School, Singapore Management University, Rotterdam School of Management and Impact Institute.

This section presents a selection of the most relevant frameworks, offering concise explanations of their methodologies and key definitions, while highlighting their alignment with the IWAF approach. The following page details how each framework was integrated into the IWAF, illustrating the pathways that link research outputs to specific impacts. Each number specifies which framework was used for each component of the pathway.

Proposed Framework

Return to contents page

The method combines different research-specific frameworks and integrates them into the overarching concept of impact pathways to capture the impact of research. The diagram below illustrates how each framework is integrated at different stages of the combined impact pathway.



1 IWAF

2 REF

3 ESI

4 SIAMPI

* The reference activity can either be 1) research of other institutions or 2) no research. This provides results that represent marginal or absolute impact, respectively.

1 Impact Weighted Accounts Framework (IWAF)

Return to contents page

Theoretical Foundations

The **Impact-Weighted Accounts Framework (IWAF)** lays the foundation for capturing the impact of research. Designed to redefine value in organisations, from a focus on maximising financial value to optimising societal impact, it provides key concepts, requirements and guidance for organisations to quantitatively assess their impact. At its methodological core is the concept of impact pathways, ensuring that real effects are measured, instead of mere intentions.

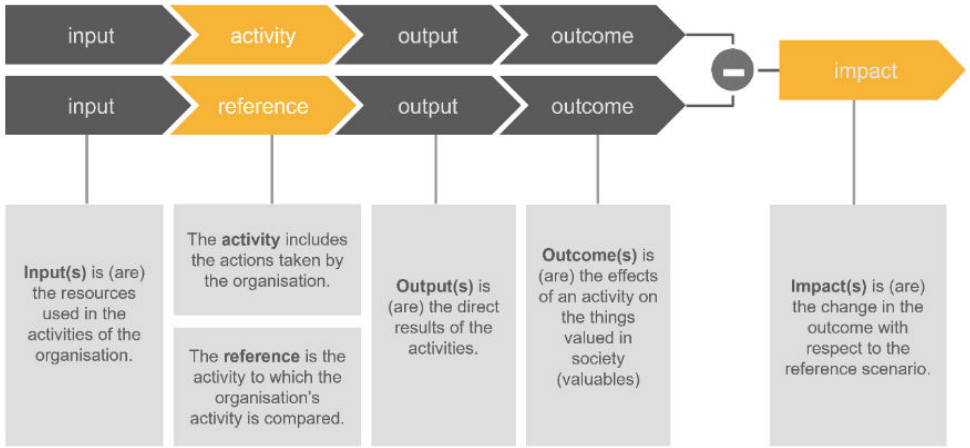
Impact → A "difference in an outcome that affects the valuables of an organisation's stakeholder with respect to a reference scenario during a given time frame".

Impact pathways → "Quantifiable chain of effects linking an organisation's specific activity to its impact through a comparison of outcomes with those in the reference activity".

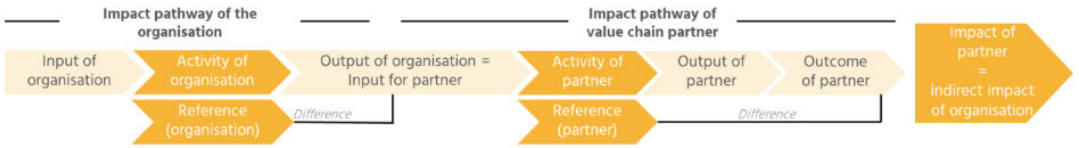
Application

- This framework provides the comprehensive foundation for mapping research institute's impact through their research activities.
- Impact pathways can capture both direct and indirect effects. Given that the impact of research depends heavily on how the research is applied by other key stakeholders, much of the impact is indirect. This is captured through "nested impact pathways".
- The contributions of various actors and activities are substantiated through research-specific frameworks.

Impact pathway



Nested impact pathway



Sources: IEF. (2022) Impact Weighted Accounts Framework

2 Research Excellence Framework (REF)

Return to contents page

Theoretical Foundations

The **Research Excellence Framework (REF)** provides a system to evaluate the excellence of research in UK higher education providers. These assessments are divided into three different categories - Outputs, Impact, and Environment – and conducted per unit of assessment that captures a discipline or group of disciplines.

Output → The published or publicly available products of research, including books, monographs, book chapters and journal articles.

Impact → The effect on, change or benefit to the economy, society, culture, public policy or services, health, the environment or quality of life, beyond academia.

Application

- While the REF does not provide quantitative indicators for measuring research impact, it identifies areas of impact with corresponding types that guide the mapping of impact pathways. This framework was instrumental in identifying the relevant impacts for academic research.
- The definition of research outputs directly informs the initial output stage of an impact pathway. This approach was used to determine which research outputs should be considered.

Impact areas

Impact areas
Impacts on the health and wellbeing of people and animal welfare
Impacts on creativity, culture and society
Impacts on social welfare
Impacts on commerce and the economy
Impacts on public policy, law and services
Impact on production
Impacts on the environment
Impacts on practitioners and delivery of professional services, enhanced performance or ethical practice
Impacts on understanding, learning and participation

Sources: REF, Guidance on Submission; REF, Panel Criteria and Working Methods

3 Evaluating Societal Impact (ESI) project of Erasmus University Rotterdam (EUR)

Return to contents page

Theoretical Foundations

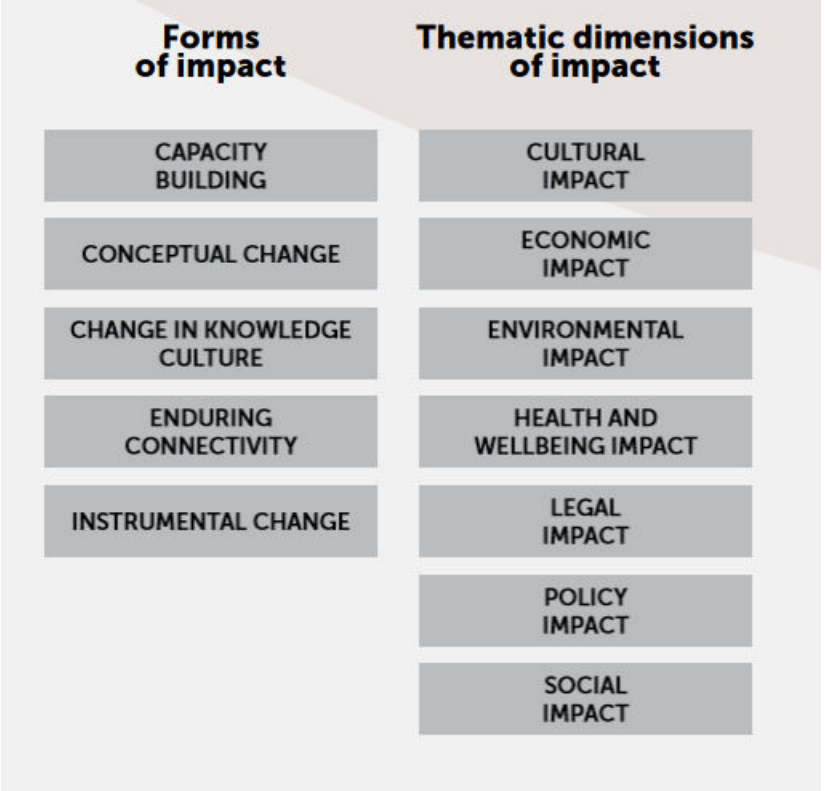
Within the Evaluating Societal Impact (ESI) project, **Erasmus University Rotterdam (EUR)** has developed a list of indicators to support academics and research units capturing how their academic work relates to society. According to ESI's approach, societal impact occurs when research helps society deal with the challenges it faces. Thereby, ESI distinguishes between forms of impact and thematic dimensions of impact. For each form or thematic dimension of impact, it provides (non-exhaustive) lists of output indicators and outcome indicators.

Output → Output indicators specify the immediate result, often the delivery of necessary results or interventions.

Outcome → Outcome Indicators show the (expected) change/effect.

Application

- The ESI framework provides a structured approach to identifying and categorising the various types of societal impact that research can achieve as well as the corresponding outcomes and outputs. This helps in systematically mapping out impact pathways.



Sources: EUR, Impact Indicators

4 SIAMPI

Return to contents page

Theoretical Foundations

The **SIAMPI framework** – Social Impact Assessment Methods for research and funding instruments through the study of Productive Interactions between science and society – defines the mechanisms through which research activities lead to a socially relevant application.

An interaction entails a contact between a research and a stakeholder, and is mediated through various means (e.g., a research publication, a policy report, committee membership, shared use of facilities or financial contributions). An interaction with research is productive when it leads to efforts by stakeholders to apply research results to social goals (i.e., when it induces behavioural change).

Application

- Emphasising the importance of societal engagement with research, SIAMPI provides the crucial link between research outputs and their effects on society.
- Productive interactions are conceptualised as constituting Activity 2 within the nested impact pathway of research. This stage involves the application and dissemination of the university's research outputs beyond the academic sphere, reaching other stakeholders.

Types of Productive Interactions

Direct Interactions

- Workshops, conferences between researchers and important stakeholders
- Collaborations – join research projects
- Consultations

Indirect Interactions

- Publications, research articles, reports and books
- Media appearances
- Media coverage
- Public lectures

Financial Interactions

- Funding and investments
- Patents
- Creation of spin-off companies

Sources: SIAMPI 230330 final report

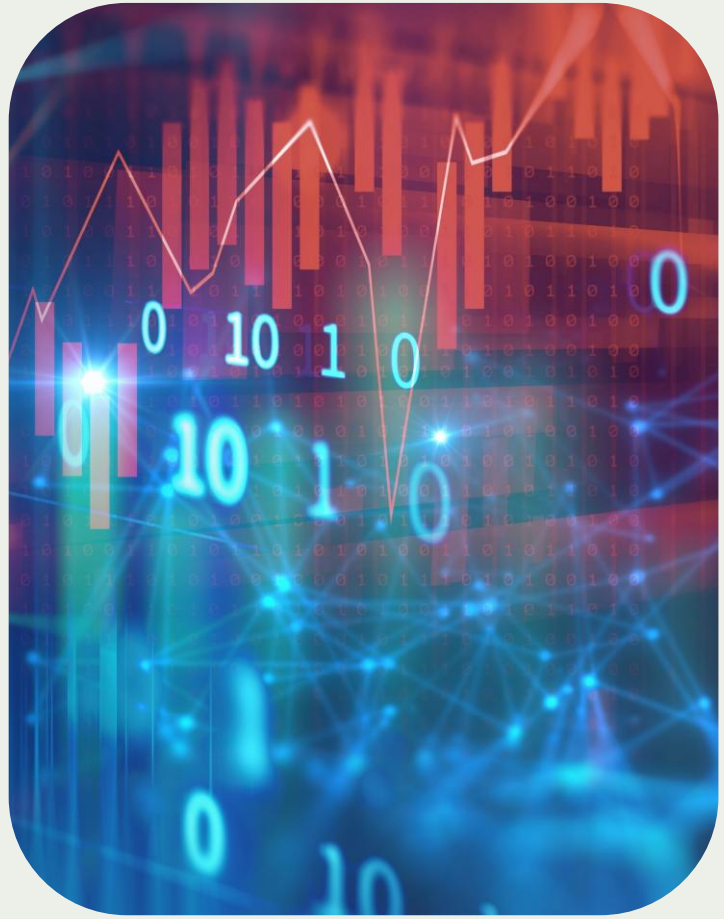
Economic Interactions

Overview

Return to contents page

Economists argue that knowledge accumulation is essential for long-term economic growth, as reflected in theories like the Solow growth model and endogenous growth theory.[1] The generation of knowledge drives the development of new products, services, processes, and business models, enhancing productivity and overall growth.[2] Given their role as centres of scientific inquiry and knowledge creation, many studies have sought to quantify *how university research activities contribute to economic development.*[3]

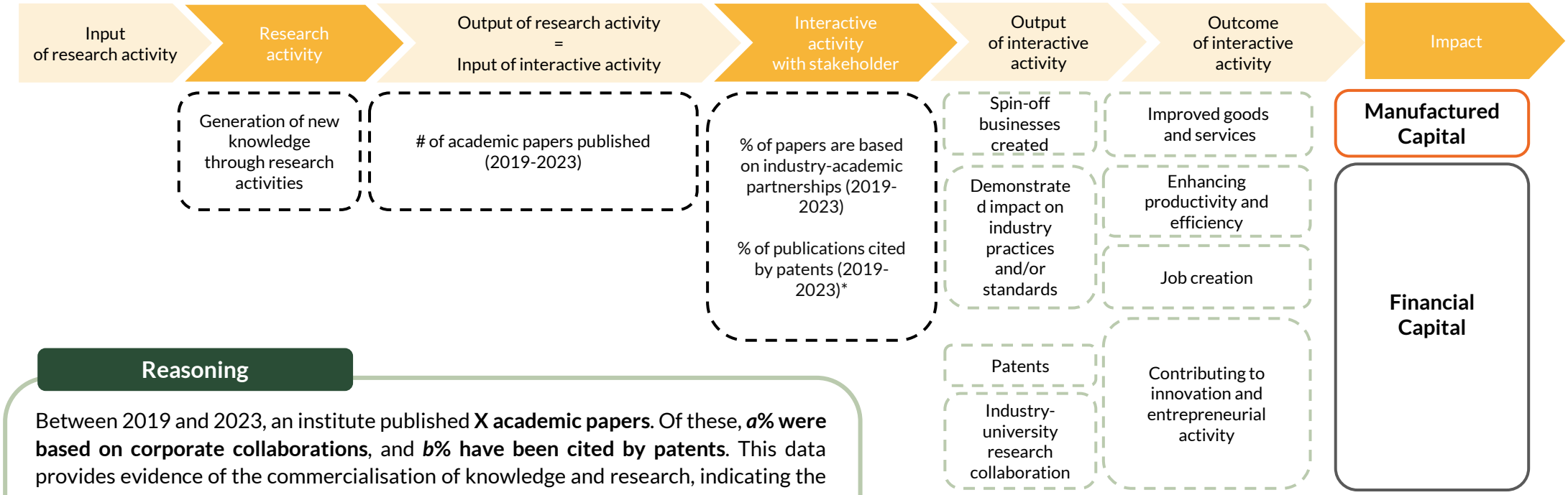
In the following pages, a pathway is presented to illustrate how academic research activities contribute to economic development. This pathway integrates the theoretical frameworks previously discussed with insights from secondary literature. However, due to data limitations, the analysis captures only a portion of academic research's influence on economic development. It is important to acknowledge that the full economic impact extends beyond what can be quantified or documented through available sources.



[1] Solow, 1956; Romer, 1986
[2] Hassan and Tucci, 2010
[3] Pinto & Teixeira, 2020; Guellec & van Pottelsberghe de la Potterie, 2001; Wong et al. 2023; Kirchhoff et al. 2007; Mark et al. 2014

Economic Interactions – Primary Data

Return to contents page



Reasoning

Between 2019 and 2023, an institute published **X academic papers**. Of these, ***a*% were based on corporate collaborations**, and ***b*% have been cited by patents**. This data provides evidence of the commercialisation of knowledge and research, indicating the institute's influence on innovation processes. However, the limitations of both primary and secondary data make it challenging to quantify the actual contribution of these collaborations on the development of new technologies, practices, and processes. This difficulty is compounded by the indirect nature of the relationship and the numerous other confounding variables which can influence it.

* It should be noted that the time-frame of the papers and patents considered was 2019-2023. Given the long-term effects of research, it is possible that the rate of patent citations will increase over time.

Datapoint available Datapoint unavailable

Economic Interactions – Secondary Data

Return to contents page

Secondary literature was consulted to bridge the gap between the primary data and the outcomes and impact related to university research activities.

Multiple studies have aimed to quantify research as a predictor of economic development using different statistical modelling methods [1,2,3,4]. On the right, examples of possible independent and dependent variables are shown.

The following pages break down the main insights from these papers and outline how they could be applied to identify academic research's impact

Example variables in statistical models

Independent variables

- Research output
- R&D expenditure
- …

Dependent variables

- GDP per capita
- Total factor productivity
- New firm formation
- ….

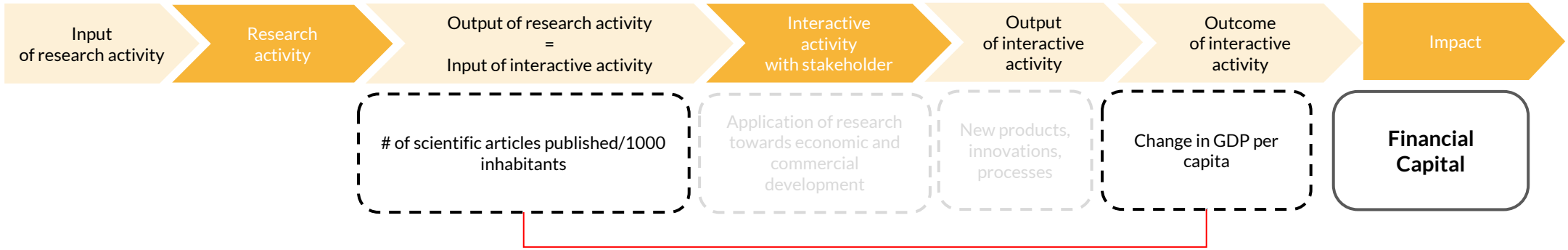
Studies included in following section

1. Pinto & Teixeira (2020)
2. Guellec & van Pottelsberghe de la Potterie (2001)
3. Wong et al. (2023)
4. Kirchhoff et al. (2007)
5. Mark et al. (2014)

Economic Interactions – Pinto & Teixeira (2020)

The impact of research output on economic growth by fields of science: a dynamic panel data analysis, 1980–2016

Return to contents page



Summary of study

- Based on a sample of 65 countries from 1980-2016
- Applied a dynamic panel Generalised Method of Moments estimation method
- Estimates the effect of scientific articles published/1000 inhabitants on real GDP per capita
- Additionally disaggregates publications by discipline to identify the impact per discipline

This effect coefficient assumes an equal contribution of each paper to GDP change. A weight factor (α) could be introduced to differentiate between, for example, quality of research. However, further research is needed to confirm and quantify the differentiating effect of research quality on GDP increase.

Applicability and suitability

- This study allows to estimate the change in real GDP per capita that can be linked to academic research output.
- The study also suggests disaggregating the impact by scientific discipline. However, this step was not taken, as it would neglect the indirect effects of the social sciences and arts & humanities (e.g., providing inspiration for other disciplines).
- A limitation is that no distinction within research output can be made based on the quality of research.

Example application

- **Singaporean population in 2023:** 5,917,648 (SingStat, 2023) [1]
- **Scientific articles published by a research institute in 2023**: X

- $X \div 5{,}917{,}648 \times 1000$ = Y articles per 1000 inhabitants
- $Y \times \alpha \times 0.227$: $PPP 2011 increase in GDP per capita for articles in 2023
- $Y \times \alpha \times 0.227 \times 5{,}917{,}648$: $PPP 2011 increase in GDP
- Adjust $PPP 2011 for inflation to obtain $PPP 2023 increase in GDP

[1] Data from Singapore was used to illustrate effects.

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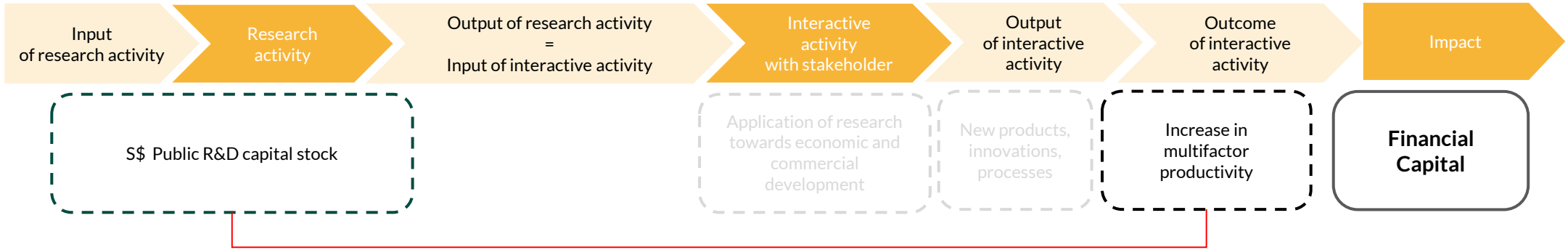
Economic Interactions – Guellec & van Pottelsberghe de la Potterie (2001)

R&D and Productivity Growth: Panel Data Analysis of 16 OECD Countries

Return to contents page



Summary of study

- Study on long-term effects of R&D types on productivity using data from 16 OECD countries (1980-1998).
- Multifactor productivity is the residual after accounting for labour and capital contributions to GDP growth.
- Total public R&D capital stock is calculated via the perpetual inventory method from higher education and public laboratory R&D expenditures.
- Examines different R&D types: business, foreign, and public (government and higher education sectors).

Applicability and suitability

- This study allows to estimate the contribution of an institute's R&D expenditure to the overall increase in multifactor productivity
- To adapt this approach, data on R&D expenditure and the proportion of that expenditure in the countries public R&D capital stock would be required.

Example application

- Data on Public R&D capital stock for Singapore 2023
- Data on public R&D capital stock for Singapore 2023 originating from research institute

- **Ratio of public R&D capital stock originating from institute × 0.17 = increase in multifactor productivity attributable to research**

* See note on weight factor in previous page for a suggestion how to differentiate between the effect of different research.

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Economic Interactions – Wong et al. (2020)

The Impact of R&D on the Singaporean Economy over 1978-2019

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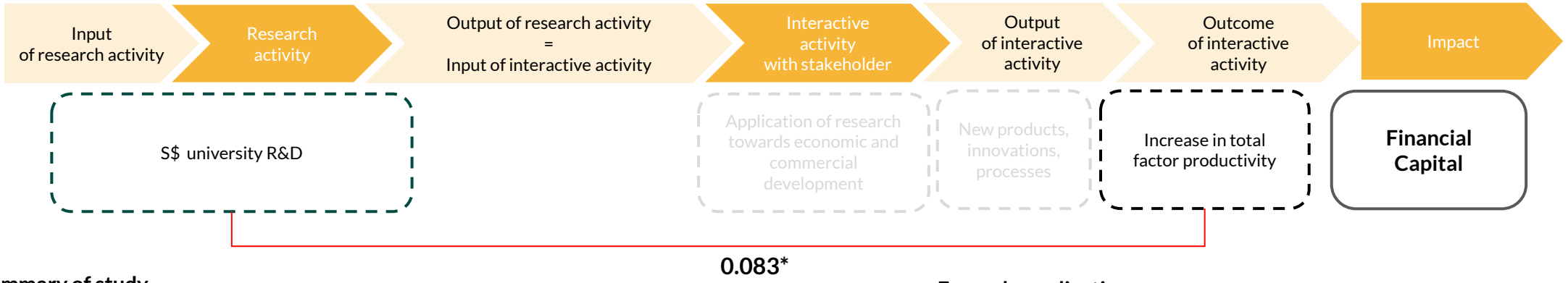

Summary of study

- A study on the impact of R&D on the economic performance of Singapore over four decades from 1978-2019.
- Economic performance is measured by total factor productivity which quantifies the portion of GDP growth which is not attributed to an increase in physical capital and labour inputs.
- The paper uses time series data, applying the Cobb-Douglas based analysis to estimate the effect of R&D on productivity.

Applicability and suitability

- This study allows to estimate how much R&D expenditure contributes to the overall increase in total factor productivity in Singapore.
- To adapt this approach, data about the ratio of a research institute's R&D expenditure to Singapore's overall R&D expenditure is needed.

Example application

- Data on Higher education R&D expenditure (HERD) Singapore 2023
- Data on research institute's R&D expenditure 2023
- Increase in TFP attributable to HERD Singapore 2023 = HERD Singapore 2023 × 0.083
- Ratio of Singaporean HERD originating from institute = Institute's R&D expenditure 2023 ÷ HERD Singapore 2023
- **Increase in TFP attributable to institute's R&D 2023 = Ratio of Singaporean HERD stemming from institute x increase in TFP related to HERD Singapore 2023**

* See note on weight factor in previous slide for a suggestion how to differentiate between the effect of different research.

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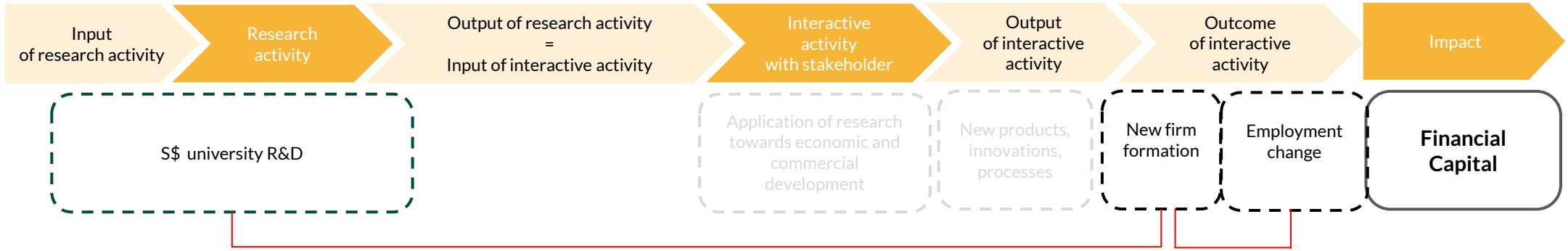
Economic Interactions – Kirchhoff et al. (2007)

The Influence of University R&D Expenditures on New Business Formations and Employment Growth

Return to contents page



Summary of study

- This study employs a localised approach, dividing the United States into distinct local economic units to examine the relationships between university expenditure and two key economic indicators: firm formation and employment change.
- A two-stage least squares regression analysis is used to jointly determine the relationship between economic development, new business formation, and R&D for the sample markets.

Applicability and suitability

- This study allows to estimate the effect of a university's R&D expenditure on local, new firm formation and the sequential increase in employment.
- To adapt this approach, the following is needed:
  - To translate the firm formation and employment change factors to Singaporean context.
  - Data on the ratio of institute's R&D expenditure to the proportion of Singapore's R&D expenditure.

Example application

- Data on Higher education R&D expenditure (HERD) Singapore 2023
- Data on research institute's R&D expenditure 2023

The following example calculation assumes the study's new firm formation and employment change factors are applicable to Singapore, even though the study's context is the USA.

- New firm births attributable to institute's R&D expenditure = HERD Singapore 2023 × 0.021
- Ratio of Singaporean HERD originating from institute = Institute's R&D 2023 ÷ HERD Singapore 2023
- New firms births attributable to institute R&D = ratio of Singaporean HERD originating from institute × new firm births attributable to university R&D

* See note on weight factor in previous slide for a suggestion how to differentiate between the effect of different research.

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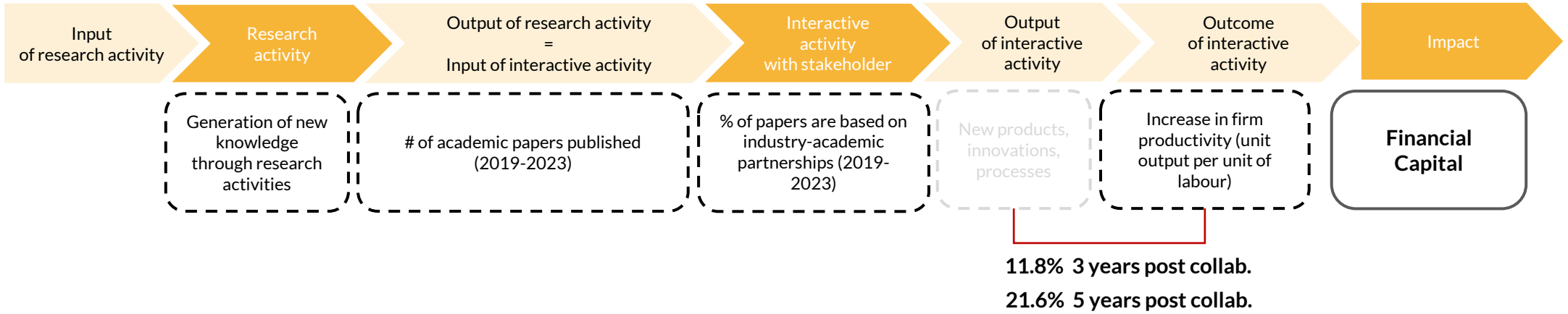
Economic Interactions – Mark et al. (2014)

Estimating the economic effects of university-industry collaboration

Return to contents page



Summary of study

- A study on university-company collaborations' impact on companies' productivity growth.
- Examines four types of formal university-company collaboration:
  - purchase of R&D from university,
  - R&D projects funded by the business and the university,
  - R&D collaboration co-funded by public R&D investment, and
  - joint scientific publications and patenting.
- The dataset considers 6,338 formal collaborations between University of Copenhagen and 1,537 private companies during the period 1998-2009.

Applicability and suitability

- This study allows to estimate how much one instance of collaboration between a research institute and an industry partner could contribute towards the company's productivity growth.
- The paper estimates that 3 years after an interaction with University of Copenhagen, companies experience a productivity return of 11.8%, increasing to 21.6% five years after establishment of the collaboration.

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Limitations

Return to contents page

Using GDP or enhanced productivity as a measure of impact	GDP measures the total value of goods and services produced in an economy but does not reflect individuals' quality of life or wellbeing. For instance, GDP per capita fails to account for income distribution, meaning that a rising GDP can mask growing inequality, with benefits concentrated among a small segment of the population. Castellacci, (2022) argues that research on the impact of innovation and technological development adopts a far too narrow definition of societal welfare. By focusing almost exclusively on material wellbeing it largely disregards non-economic factors and the distributional impacts of innovation. Studies have in fact suggested that innovation and technological progress can exacerbate income inequality (Permana et al., 2018). Moreover, GDP primarily captures short-term economic performance and overlooks long-term sustainability and resource depletion. Activities harmful to future wellbeing, like over-extraction of resources, can still positively impact GDP today. While universities contribute significantly to economic growth through research and innovation, an overemphasis on GDP-oriented outcomes may inadvertently skew research priorities.
Non-linearity of effects	The relationship between university research output and economic growth is not straightforward or linear. This complexity arises because several intermediate processes influence how research translates into economic benefits, and these processes are often not captured in simple quantitative analyses. One critical factor is the commercialisation of research. For instance, Guellec and van Pottelsberghe de la Potterie (2001) found that public R&D has a more significant impact on economic growth in countries where private sector R&D is also high. Similarly, Mark et al., (2014) argue that the benefits that companies derive from collaborating with universities highly depends on their absorptive capacity and the company's own R&D intensity. This suggests that a strong private sector is essential for effectively leveraging public research to create economic value. Moreover, the effectiveness of this translation depends on various factors, including the innovation ecosystem and the skill level of the workforce. Pinto and Teixeira (2020) further emphasise that structural changes that support the industrial sector play a crucial role in enhancing the indirect effects of research on economic growth.
Additionality of effects	The above provided examples of potential applications of studies to estimate the economic impact of academic research on society. However, these estimates of effects might overlap and double count certain economic effects. For example, increased productivity will increase GDP. Therefore, these effects cannot be added and should only be used as explorations of how the economic impact of research can be measured.
Limitations of individual studies	Each study included in this overview applied different statistical models. Each of these models come with their own limitations. These should be taken into consideration alongside the overall limitations specified above.

Policy Interactions

Overview

Return to contents page

The relationship between research and policy is complex and depends on a variety of factors. Different relationships between research and policy exist: Knowledge acquired through research can shape policy, while policy can also shape research, knowledge can be co-produced by government and academic bodies, or research and policy can exist in autonomous spheres without interactions.[1]

When research is utilised by policy makers, the utilisation can be of different quality: (1) instrumental, (2) conceptual, or (3) symbolic. Instrumental utilisation of research means that research is directly deployed and used by policy makers. Conceptual utilisation shapes the way of thinking and thus influences policies in the long-term. Symbolic utilisation of research serves to confirm choices already made.[2]

Once research is undertaken on policies, its application can take various forms. Applied to make specific policies more effective, e.g. health care services, environmental policies, and minimum wage policies, it can affect human health, ecological conditions, and poverty. Alongside such topic-specific applications, research can also affect the quality of governance in general, thereby affecting social capital. More specifically, good governance – defined by factors such as effectiveness, responsiveness, accountability, and rule of law – can improve citizens' trust in the government.[3]

The above shows that the relationship between research and policy is complex and the quantification of the impact of research on policy is not straightforward. Furthermore, empirical findings on the effects of research are scarce.

Guiding Questions

1. Which data provide input for impact pathways of research's impact on social capital through research-informed policies?
2. Does literature provide sufficient information to quantify research's impact through policies (using primary data as input)?

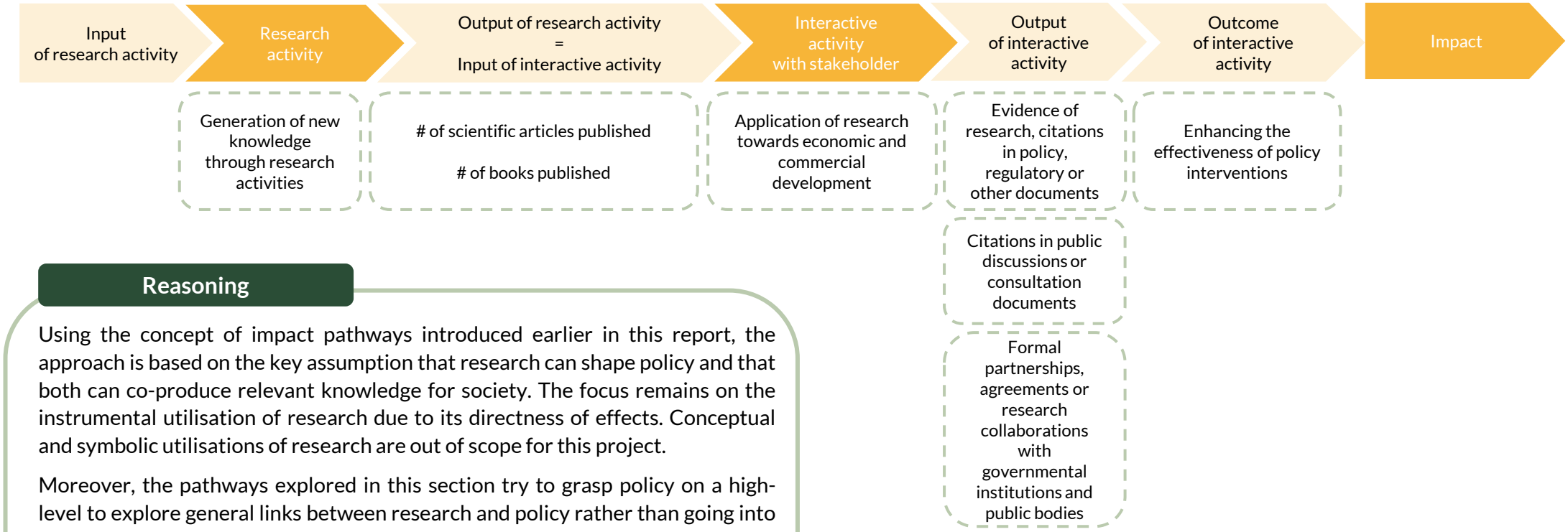
Approach

1. Provide a proof of concept of how impact pathways can be applied to measure (certain aspects of) societal impact of research through influencing policy, and
2. Identify knowledge gaps to direct data collection and future research on the topic.

[1] Boswell & Smith, 2017
[2] Amara, Oumet, Landry, 2004
[3] Mansoor, 2021

Policy Interactions – Applied Method

Return to contents page



Reasoning

Using the concept of impact pathways introduced earlier in this report, the approach is based on the key assumption that research can shape policy and that both can co-produce relevant knowledge for society. The focus remains on the instrumental utilisation of research due to its directness of effects. Conceptual and symbolic utilisations of research are out of scope for this project.

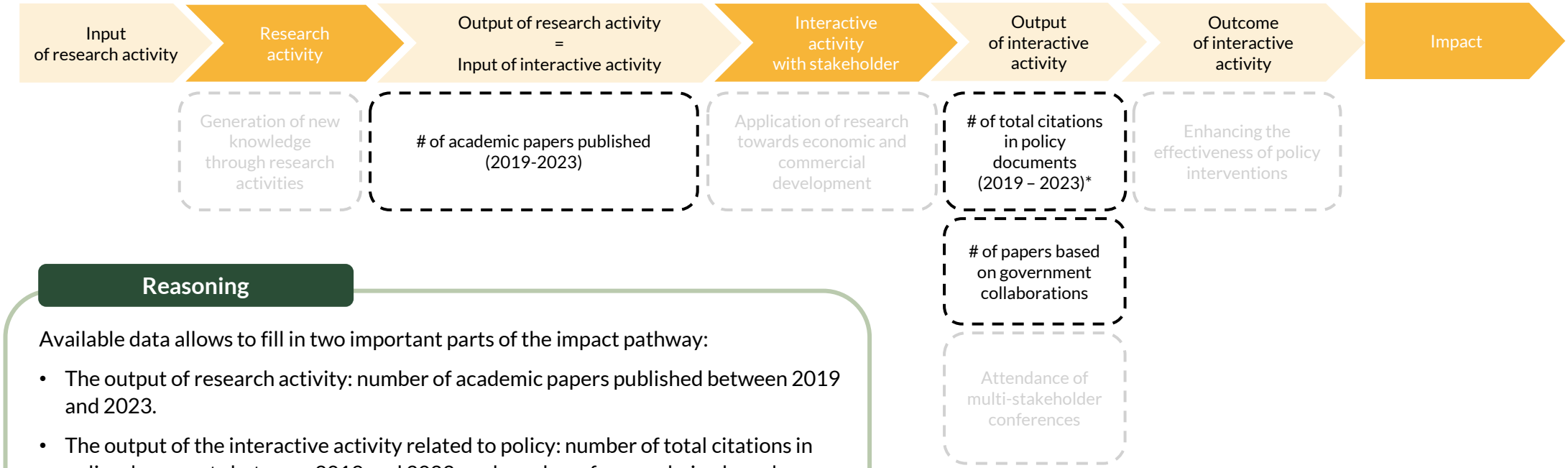
Moreover, the pathways explored in this section try to grasp policy on a high-level to explore general links between research and policy rather than going into the impact of specific policy areas, such as environmental or social policy. The latter would require the assessment of effects of research on specific policies, which is beyond the scope of this project. Instead, this section focuses on the more general effect of improved policy quality resulting from research and its subsequent effects on social capital.

Approach

Aiming to fill in the elements of an impact pathway for the impact of academic research on policy, primary data from a research institute is required. After analysing the primary data, secondary data from literature is used to fill the remaining gaps.

Policy Interactions – Primary Data

Return to contents page



Reasoning

Available data allows to fill in two important parts of the impact pathway:

- The output of research activity: number of academic papers published between 2019 and 2023.
- The output of the interactive activity related to policy: number of total citations in policy documents between 2019 and 2023, and number of papers being based on government collaborations.

Policy documents hereby encompass documents by any governmental and intergovernmental body around the globe and are not limited to the Singaporean government.

The analysis also shows that primary data on the outcome of this interactive activity (productive interaction) is not available. The next slide will investigate secondary data options that can fill (part of) these gaps with proxies.

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* It should be noted that the number of citations in policy documents might include published papers from before 2019. Likewise, papers publish between 2019 – 2023 could be taken up in research in the future.

Policy Interactions – Secondary Data

Return to contents page

Following the insights gained from primary data, the analysis of secondary data aimed to find suitable proxies to fill in the outcome step of the pathway that can be linked to the output data. For that, literature was reviewed that issued empirical studies, examining the utilisation or consultation of research by policy officials, as well as the relationship to and the effects on good governance. The findings of the chosen studies on the use of research by policy were based on surveys with policy officials of different levels, disciplines, and agencies, thereby addressing policy making on a general level.

The review also showed an empirical link between governance quality and wellbeing. While these findings allow to further populate the impact pathway for the impact of research on policy, they still leave gaps that need to filled by future empirical research.

The following pages introduce the relevant findings of the selected studies, assess their applicability and suitability, and show how the findings could inform further research to fill the remaining gaps.

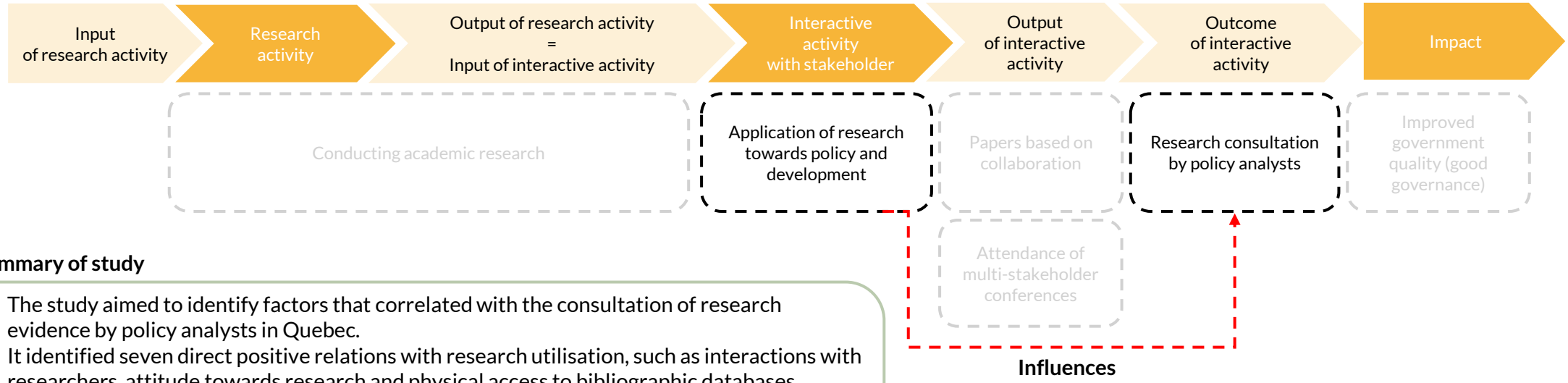
Studies included in following section

1. Bédard (2015)
2. Head et al. (2015)
3. Helliwell et al. (2018)

Policy Interactions – Bédard (2015)

The Mobilization of Scientific Evidence by Public Policy Analysts: Path Analysis and Predicted Probabilities

Return to contents page



Summary of study

- The study aimed to identify factors that correlated with the consultation of research evidence by policy analysts in Quebec.
- It identified seven direct positive relations with research utilisation, such as interactions with researchers, attitude towards research and physical access to bibliographic databases.
- It identified several indirect positive relations with research utilisation (through interactions and attitude), such as holding a master and/or doctoral degree.

Applicability and suitability

- The findings of this study do not allow to quantify the effect of interactive activities on the uptake of research in policy design. However, they do suggest that policy engagement – captured as interactive activity in this impact pathway – has a positive effect on the uptake of academic research by policy makers.
- The results also draw attention to the importance of other factors that influence research utilisation, such as academic training and type of discipline, reinforcing the notion that specific data on the Singaporean context is required.

Example application

- The data of a university shows that there were collaborations with governments between 2019 and 2023 which can be used as an indicator that the research resulting from these interactions is taken up by policy makers.
- Citations in policy documents between 2019 and 2023 can further strengthen this notion.
- A thematic analysis of which disciplines/topics were subject of the engagement (and/or consequently cited) by which governmental bodies could allow to capture the relationship between university's policy engagement and the uptake by policy makers.

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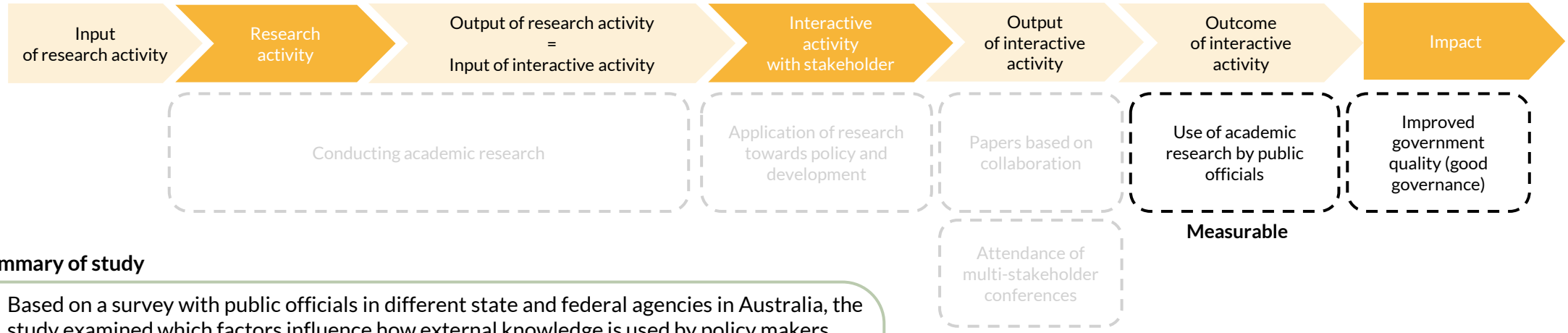
Policy Interactions – Head et al. (2015)

Are policy-makers interested in social research? Exploring the sources and uses of valued information among public servants in Australia

Return to contents page



Summary of study

- Based on a survey with public officials in different state and federal agencies in Australia, the study examined which factors influence how external knowledge is used by policy makers.
- Thereby, it focused on the perceived use of research expertise in policy work and the organisational and institutional factors that influence perceived instrumental uptake of research.
- It finds that several of these factors increase the likelihood of instrumental research uptake, such as the acknowledgement of the importance of research by colleagues, considering policy to be evidence-based and having staff whose role is linking government officials with researchers.

Applicability and suitability

- Focusing on instrumental research uptake, the results of this study provide valuable insights for an impact pathway by showing that academic research is valued and taken up by government officials and more importantly, showing that this can be measured.
- However, these findings cannot be generalised. Instead, they can inform a future study design for the Singaporean context.

Example application

- To ensure that the policy citations of research represent an instrumental uptake (opposed to symbolic), insights on how policy officials assess the use of research would be helpful.
- The survey deployed in this paper can serve as an example thereof.
- An analysis of agencies that used the research in the last 5 years, considering organisational and institutional factors pointed out in this study, would further improve the measurability of an instrumental uptake of research.

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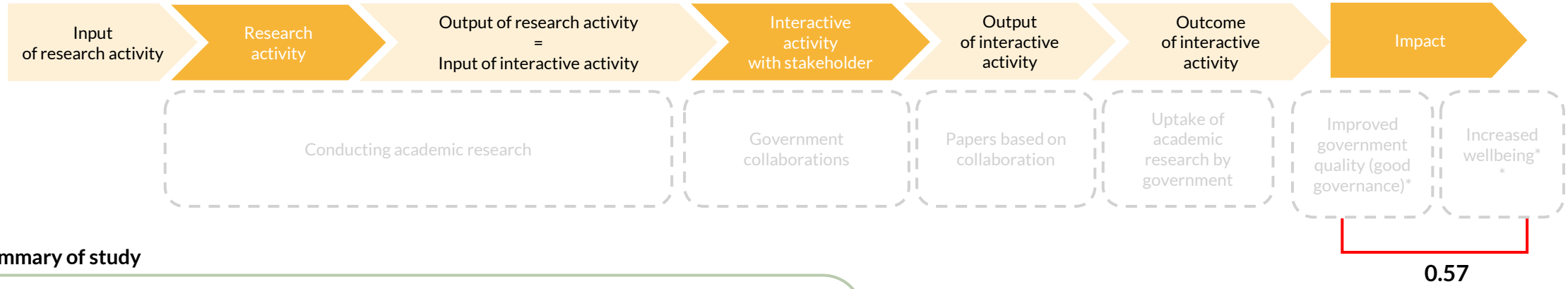
Policy Interactions – Helliwell et al. (2018)

Empirical linkages between good governance and national wellbeing

Return to contents page



Summary of study

- The study examined the extent to which governance quality contributes to wellbeing, measured through life evaluations based on national-level data.
- It deploys datasets from the World Database of Happiness (WDH) for wellbeing and the Worldwide Governance Indicators (WGI) by World Bank.
- Based on a regression analysis, the study finds that indicators related to the delivery quality of a government (i.e. government effectiveness, regulatory quality, rule of law and control of corruption) significantly correlate with increased wellbeing.

Applicability and suitability

- This study allows to quantify the relationship between improved government quality and increased wellbeing which could fill in the last step of the impact pathway: grasping the effect of an outcome that leads to a change on a valuable, in this case, wellbeing.
- However, to use these findings, an empirical link between academic research and improved government quality still needs to be identified.

Example application

- Considering the number of government collaborations, it would be worth exploring how these collaborations relate to aspects constituting good governance (i.e., government effectiveness, regulatory quality and rule of law). Such analysis would be crucial to make a link between the research output and the findings described in this study.
- Contextualising these insights with country-specific data by the Worldwide Governance Indicators and World Database of Happiness would further support the quality of such a linkage.

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Limitations

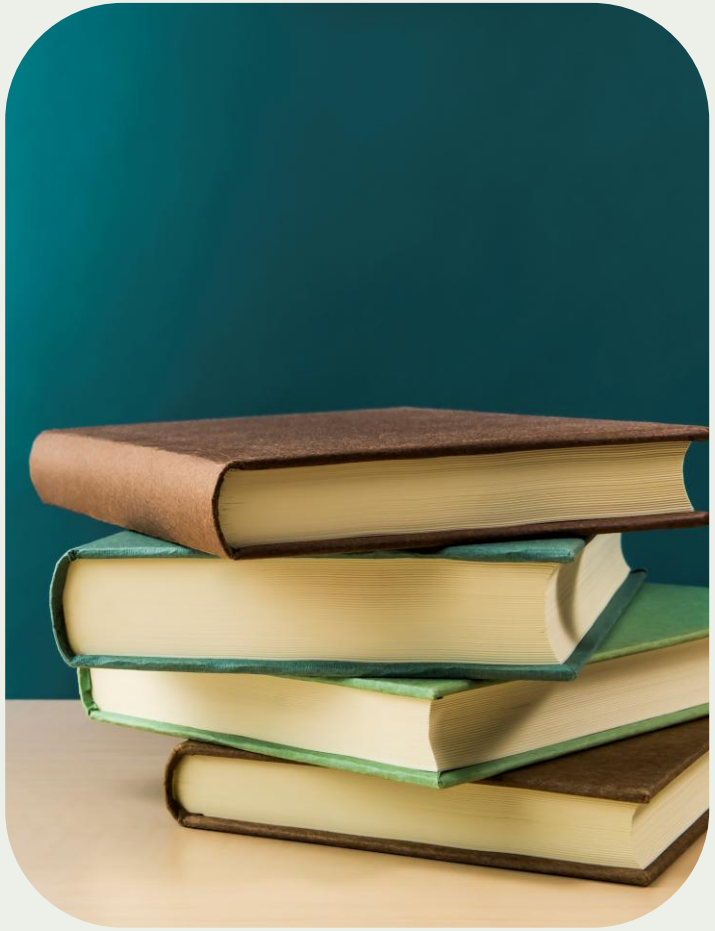
Return to contents page

No clear evidence of a causal relationship	While the findings of the included studies shed light on the different elements of an impact pathway, they do not provide evidence for a causal relationship between research and policy impact. One the one hand, there is no empirical data that captures the relationship between research uptake and good governance indicators, which would allow to link the outputs of the impact pathway with an outcome. On the other hand, the statistical models deployed by the studies to analyse research uptake help to understand the relation between policy engagement and research utilisation, but do not allow for an interpretation of causality between the two.
Policy only a means to an end	The design of this work – focusing on finding a general link between research and policy – by nature falls short of accounting for the variety of effects that policies can lead to. First and foremost, policy is only a means to an end for wellbeing, rather than an end on itself. Hence, policy must be connected to a valuable to assess the policy impact. Against this background, findings on policy impact as introduced in this report can only be a starting point. Statements on the impact of research on policy would require the classification of research content that has been utilised as well as an analysis of the influenced policies or policy-making/decision-making practices.
Limitations of individual studies: no generalization possible	The studies included in this overview, which focused on the utilization of research (Bédard, 2015; Head et al., 2015), applied different methodologies, using different surveys for different types of policy officials in different countries. While they can provide valuable insights, their findings cannot be generalised and applied to the Singaporean context without further research.

Summary - Implications for research's impact measurement

Return to contents page

- The research introduced in this section supports the general notion that instrumental research uptake by policy officials is **measurable**, and that **quantifying policy impact** can be **feasible**.
- By **highlighting current gaps**—such as missing primary data and the need for further empirical research to complete the proposed impact pathway—the **findings offer guidance** for **potential follow-up projects** aimed at developing tailored, quantified measurements of policy impact.
- The scope of this report is to illustrate a **general impact pathway for policy influence**, without considering the specific content of the policies themselves. As a result, it represents only **one of many dimensions of research's potential policy impact**.
- A more **detailed investigation into specific policies** that research has influenced, such as those related to **health** or **sustainable urban development**, would allow for the creation of more targeted impact pathways. These pathways would likely lead to a more **comprehensive assessment** and **potentially higher impact results**.



Conclusions

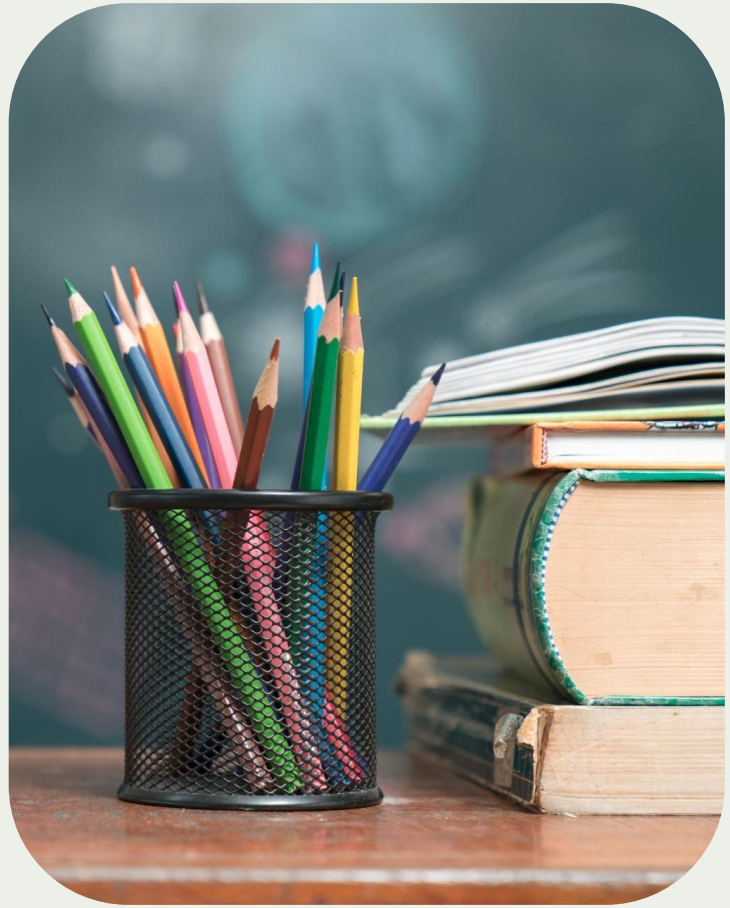
Conclusion

Return to contents page

In conclusion, this report has examined the complex and multifaceted impact of academic research on society. By integrating existing research frameworks with the Impact Weighted Accounts Framework, a robust approach for conceptualising, measuring, and analysing the contributions of academic research to societal challenges and social progress has been developed. This integrated methodology offers a nuanced perspective on how research outputs translate into real-world outcomes, providing valuable insights into the diverse ways academic institutions can drive positive change.

The framework not only captures research's current impact but also serves as a strategic foundation for identifying areas of focus to amplify future contributions. By highlighting key pathways to impact, it enables research institutes to more effectively track research contributions and strategically allocate resources to maximise societal benefits.

The following pages present several key insights from this investigation, which can guide research institutes in refining impact measurement practices and enhancing overall impact strategies. Additionally, the discussion briefly addresses the OECD Wellbeing Framework to offer insights into how wellbeing can be quantified, further enriching the institute's approach to evaluating and understanding its societal impact.



Conclusion - Key insights I

Return to contents page

Proof of Concept: A structured framework has been developed that simplifies the complex concept of research impact into more tangible components. By utilising impact pathways, the various channels through which research can influence society are highlighted. This approach dissects research impact into specific elements—outputs, activities, and outcomes—offering a more systematic method for measuring, quantifying, and assessing the societal impact of research.

Application: Our analysis demonstrates the value of this framework for examining various types of impact, while incorporating both quantitative and qualitative data.

Integration of Data: This approach demonstrates how diverse impacts can be assessed through the integration of primary and secondary data points. This information provides valuable insights into the types of data that can be collected and monitored over time to enhance the measurement of academic research's impact.

Future Research: Although a complete quantification of impact was not achievable due to data gaps, our findings offer valuable guidance for future research aimed at addressing these gaps.

Impact is indirect and Diverse: impact is indirect and diverse, making it challenging to establish causal, and quantitative relationships and attribute specific impacts. Furthermore, scientific progress is cumulative, building on prior work across various disciplines, which obscures the contributions of individual studies. The full effects of research may take years or even decades to manifest, with significant breakthroughs often resulting from the synergy of multiple efforts rather than isolated findings. External factors, such as the economic environment, societal structures, and the policy landscape, can significantly influence how research is applied and its ultimate impact, either accelerating or hindering the translation of findings into practical applications.

Qualitative Relationships: A significant portion of research's impact is related to contributions that are difficult to quantify in monetary terms. For instance, the institute's role in enhancing human capital leads to widespread benefits across various sectors. Additionally, research can shape and influence shifts in public policy or societal attitudes.

High Level vs. Specific Impact: The specific content of research can yield more targeted impacts within particular domains. For example, while the existence of research-backed policy holds intrinsic value, research specifically related to water pollution management that leads to more effective water quality conservation policies directly impacts environmental outcomes.

Conclusion - Key insights II

Return to contents page

Multiplier Effect: The cascading nature of research impact is a critical factor in evaluating scholarly contributions. Highly cited research often sparks subsequent studies, creating a compounding effect that amplifies impact over time. This highlights the temporal dimension of research impact pathways, where the full benefits of research unfold gradually and indirectly.

Quality of Research: The quality of research published by a university should also be considered when assessing its overall impact compared to other institutes. Metrics such as Field-Weighted Citation Impact (FWCI) offer valuable insights by comparing a research article's citation count to the average expected for similar publications in the same field, type, and publication year. This information can be used as a foundation for developing a weighted conversion method to further analyse the university's research impact.

Discipline Differentiation: Different fields and disciplines can exhibit varying types and levels of impact. Currently, the quantitative economic impact of research is assessed based on aggregated publications, making it challenging to differentiate impact across disciplines. This difficulty arises from the complexities involved in attributing specific research outcomes to individual fields.

Limitations of economic indicators: While efforts have been made to capture the quantitative relationship between university research and economic growth, these studies are limited by their focus on indicators of economic development related to GDP growth and productivity. Although these metrics provide insights into increasing societal wealth, they fall short of capturing overall societal wellbeing. An overemphasis on GDP-oriented outcomes may inadvertently skew research priorities. Please refer to the next slide for a more holistic overview of indicators relevant to quantifying effects on wellbeing.

Conclusion - Quantifying Wellbeing

Return to contents page

OECD Framework on Wellbeing

- Income and Wealth
- Knowledge and Skills
- Work and Job Quality
- Subjective Wellbeing
- Housing
- Work-life balance
- Environment Quality
- Safety
- Health
- Civil Engagement
- Social Connections

Sources: OECD Wellbeing Framework
World Health Organisation

The OECD Wellbeing Framework exists to provide a comprehensive approach to assessing and improving the wellbeing of individuals, communities, and societies. This framework is valuable because it extends beyond GDP and economic growth to provide a more holistic and multidimensional understanding of societal welfare. It captures current wellbeing by distinguishing 11 underlying key dimensions. For each dimension, several measurable indicators can be defined. This framework is particularly useful for defining in quantifiable terms, the outcome step of an impact pathway, as it highlights which effects and indicators are most critical for enhancing human wellbeing. In the textbox below is an example illustrating how these dimensions can be captured quantitatively by different indicators, and how the resulting metrics can be valued monetarily.

Example

Health is a crucial dimension of wellbeing within the OECD framework, and its impact can be effectively quantified using Disability-Adjusted Life Years (DALYs). DALYs provide a comprehensive measure of the burden of diseases and health conditions by accounting for both the quality and quantity of life lost. This metric can be monetised through the Value of a Statistical Life (VSL) approach, which estimates the economic value individuals place on reducing mortality risk.

Note: Due to data limitations, it was not feasible to map in quantifiable terms, the impact of academic research on these different indicators.

Conclusion - Next Steps

Return to contents page

Productive Interactions

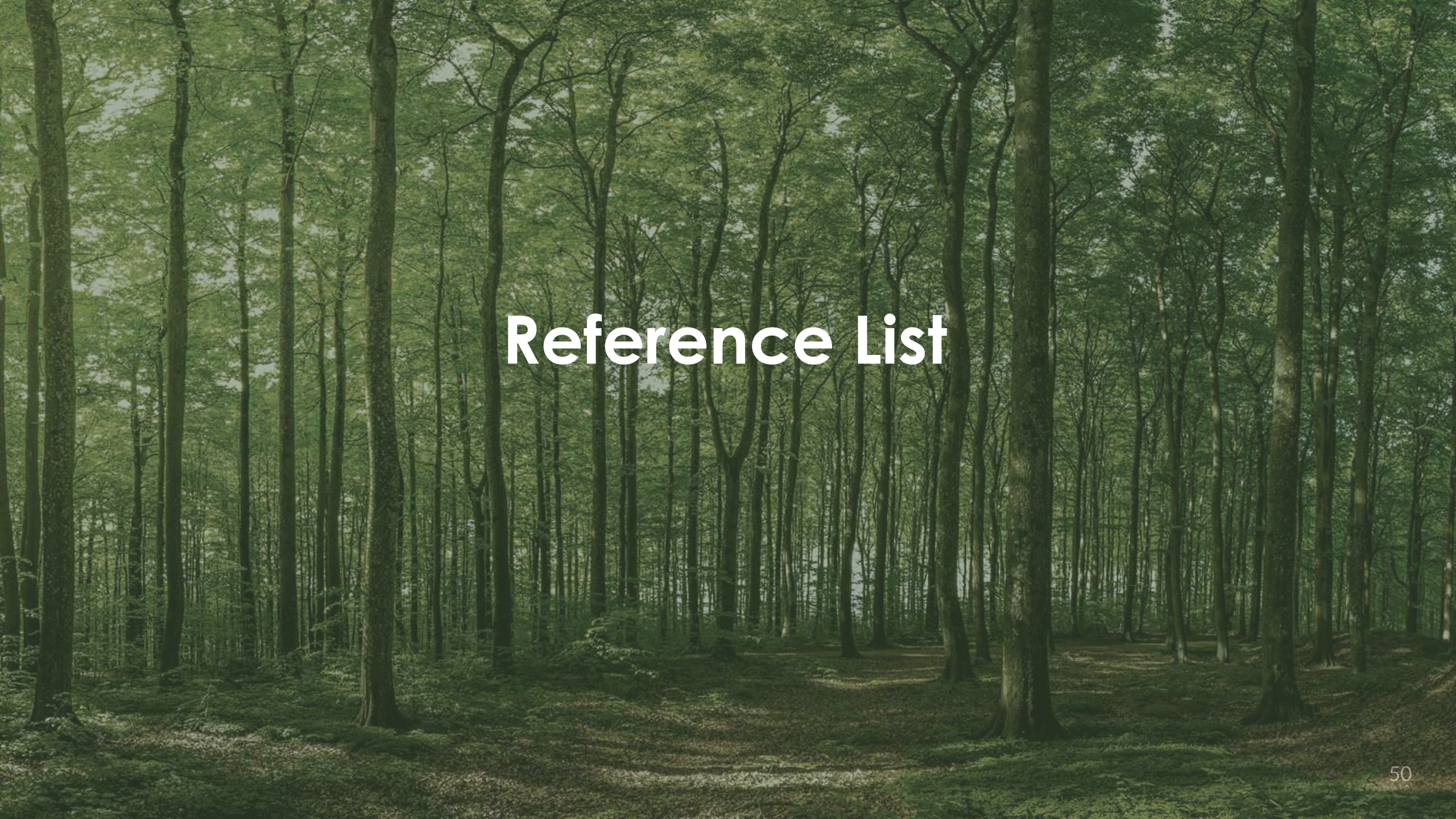
The pathways underscore the essential role of interactive engagement in maximising the impact of academic work. In alignment with the SIAMPI framework, it is important to recognise that impact extends beyond the mere creation of knowledge to include its effective dissemination and utilisation. Therefore, research institutes could focus on developing metrics to assess both the quantity and quality of these interactions, including the diversity of stakeholders involved and the tangible outcomes of collaborations. Measuring outputs of interactive activities, such as collaborative projects, public engagements, or policy consultations, can also serve as proxies for trying to capture more intangible and qualitative impact relationships.

Beyond Economic Growth

Expanding the scope of impact assessment to include a variety of important indicators related to societal development and progress will provide a more comprehensive understanding of the research's contributions. This broader perspective will enable research institute to prioritise initiatives that foster meaningful societal wellbeing and progress beyond GDP growth.

Data Collection

By developing a more structured and broader scope of data collection, research institutes can set into a motion a more formalised and structure approach for tracking and monitoring their impact over time.



Reference List

List of References I

Return to contents page

- Amara, N., Ouimet, M., & Landry, Ré. (2004). New Evidence on Instrumental, Conceptual, and Symbolic Utilization of University Research in Government Agencies. *Science Communication*, *26*(1), 75–106. https://doi.org/10.1177/1075547004267491
- Antonelli, C., & Fassio, C. (2016). Academic knowledge and economic growth: are scientific fields all alike? Socio-Economic Review, 3, 537–565
- Bédard, P.-O. (2015). The Mobilization of Scientific Evidence by Public Policy Analysts: Path Analysis and Predicted Probabilities. *SAGE Open*, *5*(3), 215824401560419. https://doi.org/10.1177/2158244015604193
- Boswell, C., Smith, K. Rethinking policy 'impact': four models of research-policy relations. *Palgrave Commun* **3**, 44 (2017). https://doi.org/10.1057/s41599-017-0042-z
- Castellacci, F. (2022). Innovation and social welfare: A new research agenda. *Journal of Economic Surveys*, 37(4), 1156-1191. Innovation and social welfare: A new research agenda - Castellacci - 2023 - Journal of Economic Surveys - Wiley Online Library
- Department of Statistics Singapore. (2023). Population and Population Structure. Available at: DOS | SingStat Website - Population and Population Structure - Latest Data
- IEF. (2024). Impact-Weighted Accounts Framework. Impact Economy Foundation. Available at https://impacteconomyfoundation.org/impactweightedaccountsframework/impactweighted-accounts-framework-document.
- Frantzen, D. (2000). Innovation, international technological diffusion and changing influence of R&D on productivity. Cambridge Journal of Economics, 24(2), 193–210.
- Grant J, Green L, Mason B. Basic research and health: a reassessment of the scientific basis for the support of biomedical science. Res Eval 2003;12:217 –24
- Grove, G. (2022). Academic reputation "still driven by journal prestige" – survey. Times Higher Education, August 3.
- Guellec, D., & van Pottelsberghe de la Potterie, B. (2001). R&D and Productivity Growth: Panel Data Analysis of 16 OECD Countries. OECD Science, Technology and Industry Working Papers. 652870318341.pdf (oecd-ilibrary.org)
- Hasan, I., & Tucci, L.C. (2010). The innovation –economic growth nexus: *Global evidence. Research Policy*, 39, 1264-1276. The innovation–economic growth nexus: Global evidence - ScienceDirect
- Head, B., Ferguson, M., Cherney, A., & Boreham, P. (2014). Are policy-makers interested in social research? Exploring the sources and uses of valued information among public servants in Australia. *Policy and Society*, *33*(2), 89–101. https://doi.org/10.1016/j.polsoc.2014.04.004

List of References II

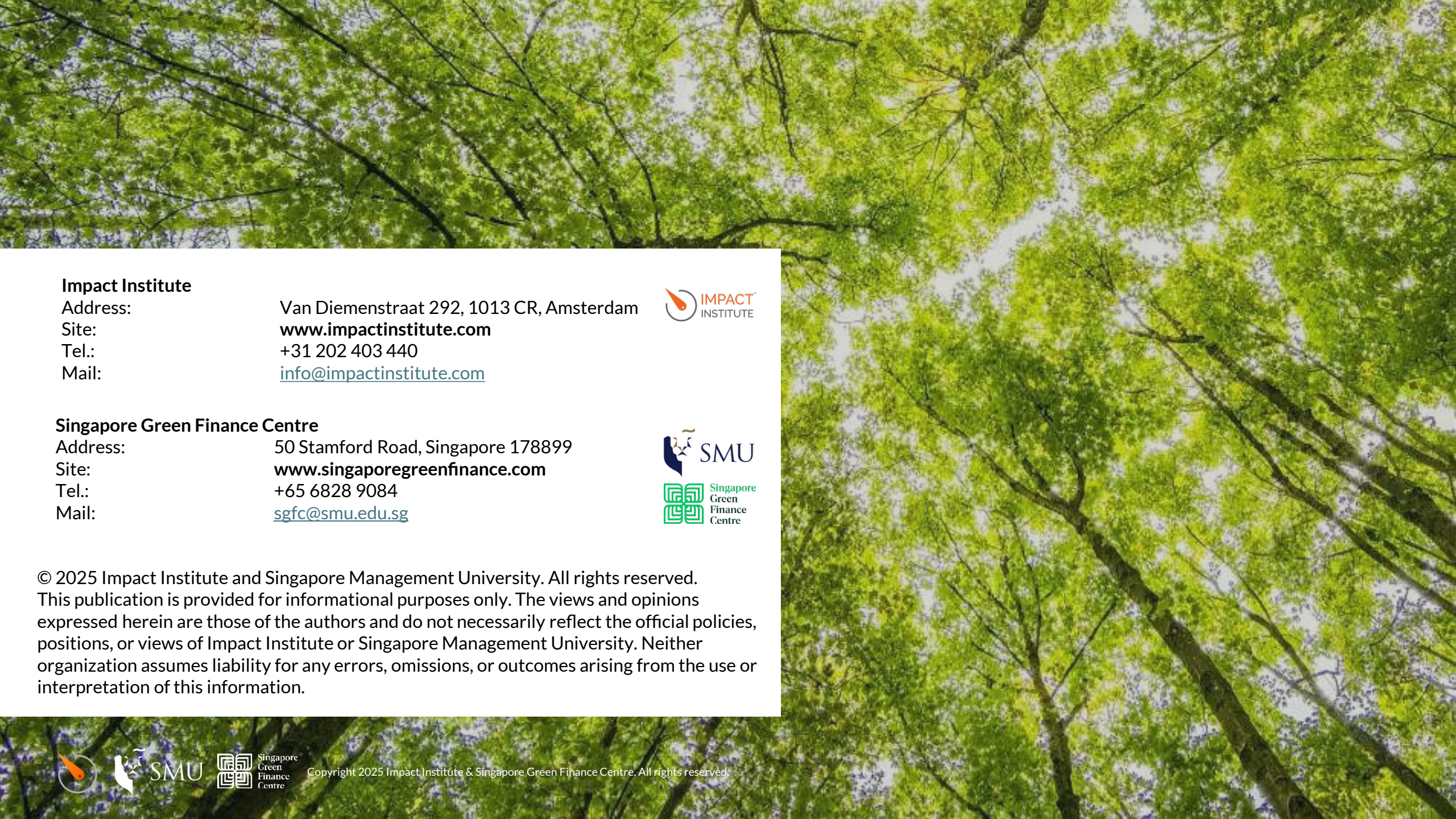
Return to contents page

- Helliwell, J. F., Huang, H., Grover, S., & Wang, S. (2018). Empirical linkages between good governance and national well-being. *Journal of Comparative Economics*, *46*(4), 1332–1346. https://doi.org/10.1016/j.jce.2018.01.004
- Kirchhoff, A.B., Newbert, L.S., Hasan, I., Armington, C. (2007). The Influence of University R&D Expenditures on New Business Formations and Employment Growth. Entrepreneurship Theory and Practice, 31(4), 543-559. The Influence of University R & D Expenditures on New Business Formations and Employment Growth - Bruce A. Kirchhoff, Scott L. Newbert, Iftekhar Hasan, Catherine Armington, 2007 (sagepub.com)
- Leydesdorff, L., & Wagner, C. (2009). Macro-level indicators of the relations between research funding and research output. Journal of Informetrics, 3(4), 353–362
- Mansoor, M. (2021). Citizens' trust in government as a function of good governance and government agency's provision of quality information on social media during COVID-19. *Government Information Quarterly*, *38*(4), 101597. https://doi.org/10.1016/j.giq.2021.101597
- Mark, M., Jensen, L.R., Norn, T.,M. (2014). Estimating the economic effects of university-industry collaboration. *International Journal Technology Transfer and Commercialisation*, 13 (1/2), 80-106. Estimating the economic effects of university-industry collaboration | International Journal of Technology Transfer and Commercialisation (inderscienceonline.com)
- Morris, Z. S., Wooding, S., & Grant, J. (2011). The answer is 17 years, what is the question: understanding time lags in translational research. *J R Soc Med*, 104, 510 – 520.
- Monetary Authority of Singapore (2023). Goods & Services Inflation Calculator. Available at: MAS | Inflation Calculator
- OECD (2020), How's Life? 2020: Measuring Well-being, OECD Publishing, Paris, https://doi.org/10.1787/9870c393-en.
- Permana , Y.M., Lantu, C.D., Suharto, Y. (2018). The Effect of Innovation and Technological Specialization on Income Inequality. *Problems and Perspectives in Management*, 16(4), 51-63. The effect of innovation and technological specialization on income inequality – DOAJ
- Pinto, T., & Teixeira, A. A. C. (2020). The impact of research output on economic growth by fields of science: A dynamic panel data analysis, 1980–2016. Scientometrics, 123(2), 945–978. https://doi.org/10.1007/s11192-020-03419-3
- Quatraro, F. (2010). The economics of structural change in knowledge. New York: Routledge.
- Romer, P. M. (1986). Increasing Returns and Long-Run Growth. Journal of Political Economy, 94(5), 1002-1037.

List of References III

Return to contents page

- Sivertsen, G., & Meijer, I. (2020) Normal versus Extraordinary societal impact: how to understand, evaluate, and improve research activities in their relations to society? *Research Evaluation* 29(1), 66-70. https://doi.org/10.1093/reseval/rvz032
- Solow, R. M. (1956). A Contribution to the Theory of Economic Growth. The Quarterly Journal of Economics, 70(1), 65-94.
- Teixeira, A. A. C., & Queirós, A. S. S. (2016). Economic growth, human capital and structural change: A dynamic panel data analysis. Research Policy, 45(8), 1636–1648.
- World Health Organization (WHO). (2019). Disability-Adjusted Life Year (DALY). https://www.who.int/data/gho/indicator-metadata-registry/imr-details/158.
- Wong, P., Ho, Y., Singh, A. (2023). The Impact of R&D on the Singaporean Economy over 1978-2019. The Singapore Economic Review, 1-27. https://worldscientific.com/doi/epdf/10.1142/S0217590823500480.
- Wratschko K. Empirical Setting: The pharmaceutical industry. Strategic Orientation and Alliance Portfolio Configuration. New York, NY: Springer, 2009.



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