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S&T Analysis and Management of Innovation Activity IV (STAMINA IV)

Benefit Statements, Benefit-Cost-Risk Analysis, and Integration of Key Performance Indicators (KPIs) and Indicators of Success (IoS) into the S&T Business Process Flow (BPF)

Appendix C: Literature Review of Performance Measurement of R&D Projects

FY24 Annual Report
For Period September 29, 2023, to September 28, 2024

September 28, 2024

DHS Science and Technology Directorate (S&T)
Office of Science and Engineering (OSE)
Technology Scouting and Transition Division (TST)

Basic Ordering Agreement (BOA): HSHQDC-17-A-B0004
Contract No. 70RSAT22G00000007
Order No. 70RSAT23FR0000080

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This research was supported in whole or in part with Federal funds from the US Department of Homeland Security (DHS) through the Center for Risk and Economic Analysis of Threats and Emergencies (CREATE) at the University of Southern California (USC) under Basic Ordering Agreement HSHQDC-17-A-B0004 / 70RSAT22G00000007 / 70RSAT23FR0000080. This report does not necessarily reflect the views or policies of DHS, nor does mention of trade names, commercial products, or organizations imply endorsement by the U.S. Government. Furthermore, any opinions, findings, and conclusions or recommendations in this document are those of the authors and do not necessarily reflect views of DHS, or USC, or CREATE.

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Executive Summary

This Appendix summarizes a review of the literature on performance measurement of R&D projects using Key Performance Indicators (KPIs) and Indicators of Success (IoS) in support of Task 3, Framework, Methodology, and Guide for Evaluating Key Performance Parameters (KPIs) and Indicators of Success (IoS) of R&D Transition Products. Each article was examined for its perspectives and indications of KPIs and IoS and was highly influential in developing the classification of KPIs and IoS categories for enabling a focus on an R&D project's transition-specific performance, as shown in Table E-1. Each article was examined for its discussion of KPIs and IoS in the context of these three major categories.

Table E-1. Classification of KPIs and IoS for R&D Performance Assessment.

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C1. 2023 Industrial Research Labs and R&D productivity

In the research context, the study challenges the conventional belief that the decline in U.S. research and development (R&D) productivity is tied to the demise of industrial research labs. Instead, it reveals a persistent and increasing presence of such labs from 1921 to 1998. The data suggests a counterintuitive "lab penalty," indicating a negative correlation between having a research lab and R&D productivity. This lab penalty is quantified as an average decrease of 5.2% in R&D productivity for firms with research labs. The parochialism of these labs, characterized by a focus on scientific goals over commercial objectives, is a significant factor contributing to the observed decline in productivity at the Research Level.

At the Transition and Operational User Benefit Level, the study emphasizes the impact of parochialism, indicating that labs disconnected from external sources of innovation may hinder user-centric outcomes. The findings suggest that a rise in research labs might have contributed to the decline in overall R&D productivity, challenging the common narrative of their demise. The IBM, Dell, Hasbro, and Mattel cases underscore the need for a nuanced understanding of the role of research labs and their influence on user benefits. The study concludes by emphasizing the importance of comprehending research labs' strategic rationale and dynamics to shape positive innovation outcomes at multiple levels.

At the Financial Level, the IBM and Dell case studies illustrate contrasting approaches to R&D and commercial success. Historically known for its research labs, IBM shifted its focus from product-oriented R&D to pure science, leading to a decline in internally created products. The emphasis on generating patents for licensing rather than developing marketable products contributed to a diminishing impact on commercialization efforts. On the other hand, Dell, without a traditional research lab, embraced an entrepreneurial and market-driven approach. By assembling components and adopting a direct-to-consumer model, Dell maintained a higher Research Quotient (RQ) and greater commercial success than IBM. The case studies highlight the importance of strategic flexibility and responsiveness to market demands for commercialization success.

Research Level
● Lab penalty
● Characteristics of research labs
Transition and Operational User Benefit Level
● User satisfaction index
● User-centric innovation rate
● Product adaptation rate
● User feedback loop time
● Accessibility and inclusivity index
● Loyalty and retention rate
Financial Level
● Research quotient
● Time to market
● Revenue from new products
● Patent quality and licensing revenue

C2. 2022 What is the societal impact of university research? A policy-oriented review to map approaches, identify monitoring methods and success factors

To measure the societal impact of university research, the paper highlights a progressive shift from ‘attribution,’ i.e., looking for causal relationships between research and societal changes, to ’contribution,’ acknowledging researchers’ efforts to engage with societal challenges. To do this, new, alternative metrics, ‘altmetrics’, have been developed to overcome the limitations of typical bibliometric indicators that track research impact from scholar to scholar. Alternate metrics aim to track the online dissemination of research outputs to non-academic audiences and have four key advantages: i) they consider broader databases beyond the traditional scholarly archives like WoS or Scopus; ii) they allow for tracking different channels and types of dissemination, iii) they are faster than academic citations, providing (almost) real-time indicators, and iv) they are openly available. Examples of altmetrics include social media mentions, downloads and views, or online discussions.

The fundamental idea of the article is that (university) research should contribute to addressing societal challenges and not just pursue ‘scientific excellence.’ Several approaches have been developed, but the definition of ‘societal impact’ is still up to interpretation.

This paper seeks to outline the scientific discourse on the scientific impact of university research. It discusses three key aspects: 1) the existing conceptualizations, 2) the methods and indicators employed for monitoring and evaluation, and 3) the factors contributing to success.

This paper examines the scientific literature on the 'societal impact' of university research, reviewing 135 relevant publications. It explores conceptualizations, monitoring methods, and success factors in response to increasing policy demands on universities to address societal challenges. The review advocates for broader, longer-term perspectives on research impacts, from seeking causal relationships to recognizing researchers' contributions in addressing societal challenges.

To address the limitations of traditional bibliometric indicators, new metrics called 'altmetrics' have been created. Unlike mainstream indicators focusing on scholarly impact, altmetrics track the online spread of research outputs to non-academic audiences, emphasizing the impact 'from-scholars-to-society'.

Altmetrics have four key advantages: i) they consider broader databases beyond the traditional scholarly archives like WoS or Scopus; ii) they allow for tracking different channels and types of dissemination, iii) they are faster than academic citations, providing (almost) real-time indicators, and iv) they are openly available.

Fostering 'productive interactions' between researchers and societal stakeholders is suggested as an effective strategy for co-producing and co-creating research, directing university efforts toward addressing societal challenges.

C3. 2020 Managing innovation performance: Results from an industry-spanning explorative study on R&D key measures

Out of 154 R&D performance measures that were developed, ten key R&D performance measures were selected. Following are the ten key performance measures identified:

- Input indicators include budget spent on applied research, budget spent on basic research, hours spent on project vs. total hours R&D, innovation level and degree of creativity, and project progress/projects completed
- Output indicators include the transfer rate of new knowledge and technology into product development, % of projects abandoned after partial completion, the degree of anticipativeness to internal customer needs, % of new tech content in new products, and planning accuracy.

The authors also outline characteristics of a successful measurement system: focus on external vs. internal measurement, measure outcomes and outputs rather than behavior, measure only valuable accomplishments/outputs, make the measurement system simple and objective, and separate R&D evaluation. In addition, the transfer rate of new knowledge and technology into product development was identified as a known and useful measure in the descriptive survey. It stood out as one of the only two key R&D performance measures selected by both focus groups, unlike the number of technology transfer plans, which didn't progress past the descriptive survey stage due to being deemed not applied or useful.

Research on R&D performance measures in firms remains limited. Using a mixed-method approach grounded in literature and text analysis, 154 R&D performance measures were developed. Through an online expert survey and independent focus group workshops with industry experts across more than ten industries, ten key R&D performance measures were identified and validated.

Unlike earlier research, certain measures, such as the degree of anticipation of internal customer needs, were considered significant by both the survey respondents and the focus groups.

In previous research, a restricted set of measures has been commonly applied to evaluate the impact of innovation on R&D performance. Examples include the quantity or quality of patents (measured by citation counts), cost and resource allocation, and external collaboration. Additionally, metrics such as return on investment and time-to-market, which are challenging to directly attribute to R&D activities, are frequently utilized.

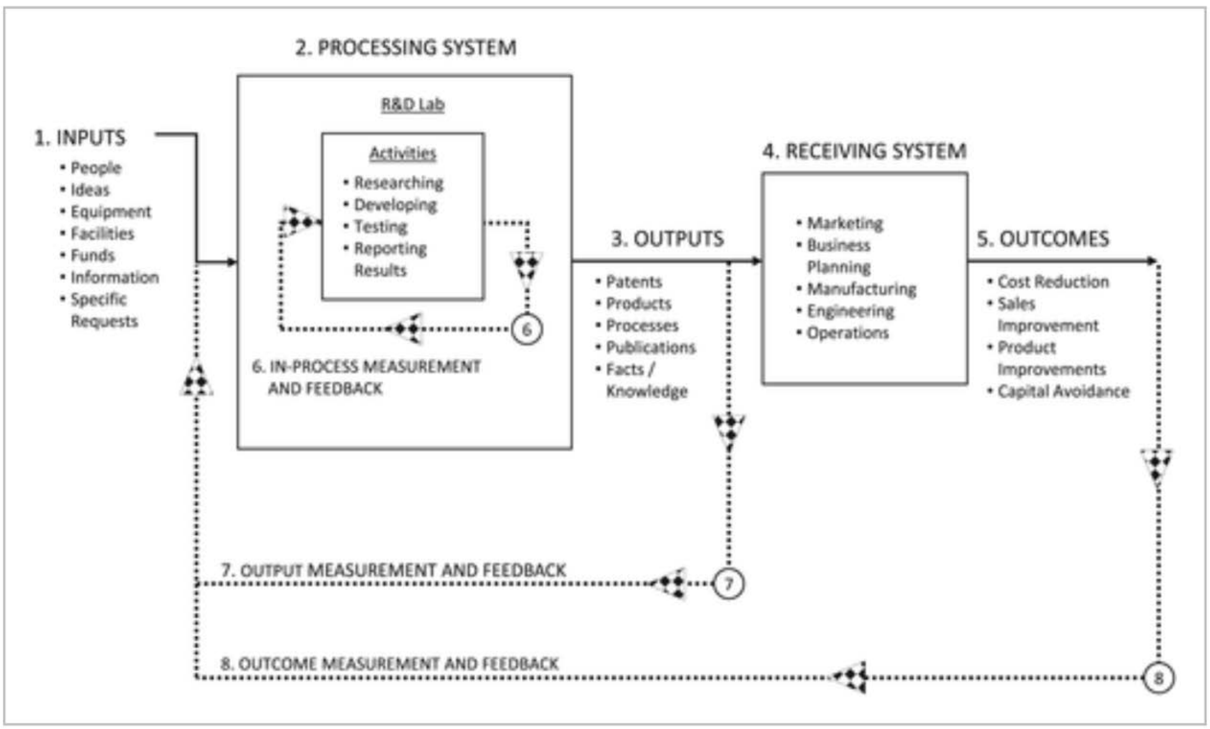
While there is literature on performance measurement, there are limited studies specifically concentrating on innovation performance measurement within the context of R&D management. To identify key measures of R&D performance from existing literature, the authors adopt the definition of R&D by Wheelwright and Clark, which states, "Research and development is the creation of the know-how and know-why of new materials and technologies that eventually translate into commercial development."

In their approach, the authors use the established definitions of performance, performance measurement, and performance measure by Neely, Mills, Platts, Gregory, and Richards. Performance is defined as "the efficiency and effectiveness of action," performance measurement as "the process of quantifying the efficiency and effectiveness of action," and a performance measure as "a metric used to quantify the efficiency and effectiveness of action."

Brown and Svenson (1998) criticize the excessive reliance of firms on internal process measurements and the predominant focus on behavior, leading to the measurement of questionable outputs such as the number of research proposals or published papers. They distinguish between measures of activity (what people do at work) and accomplishments (what people achieve at work). To address these challenges, Brown and Svenson propose six characteristics of a successful measurement system:

(1) Focus on external vs. internal measurement
(2) Focus on measuring outcomes and outputs, not behavior
(3) Measure only valuable accomplishments/outputs
(4) Make the measurement system simple
(5) Make the measurement system objective
(6) Separate R&D evaluation

Brown and Svenson (1998) designed a system for R&D measurement, outlined below, which is a crucial concept linking R&D and performance measurement.

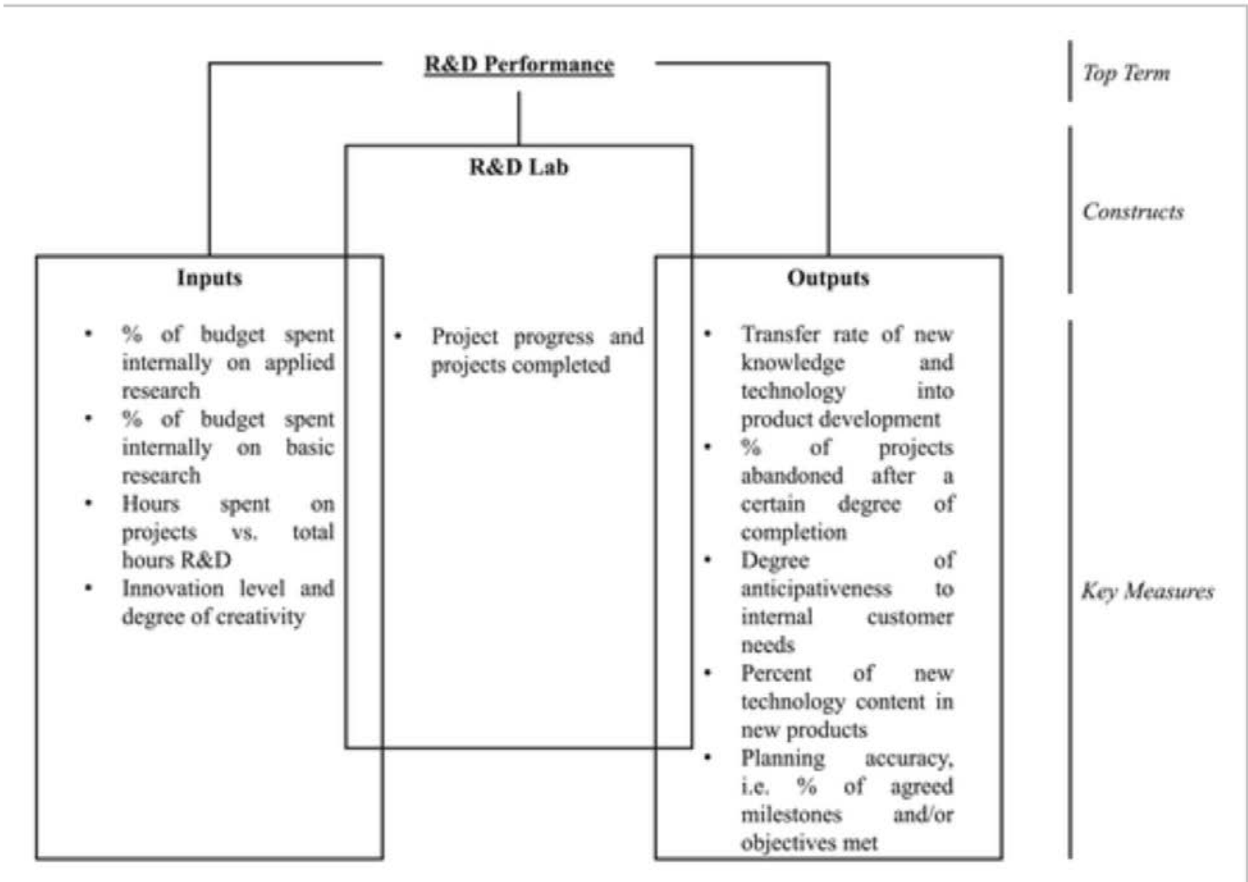


The significance of technology transfer, often assumed in prior literature without much validation, was not initially a core measure in the original R&D Lab model. However, in a descriptive survey, the transfer rate of new knowledge and technology into product development was recognized as known and useful. Surprisingly, this measure was identified as one of only two key R&D performance measures selected by both focus groups. In contrast, the number of technology transfer plans did not progress past the descriptive survey stage, as it was not considered applied or useful.

Following are the ten key performance measures identified:

Input indicators:
1) Budget spent on applied research
2) Budget spent on basic research
3) Hours spent on project vs. total hours R&D
4) Innovation level and degree of creativity
5) Project progress and projects completed

Output indicators:
1) Transfer rate of new knowledge and technology into product development
2) % of projects abandoned after partial completion
3) Degree of anticipativeness to internal customer needs
4) % of new tech content in new products
5) Planning accuracy



The authors' approach aimed to identify critical R&D performance measures, focusing on a structured derivation of these measures from prior literature.

Even though the sample and basis of analysis consisted of more than 40 industry experts in the focus groups alone, this basis could benefit from additional data to facilitate further quantitative validation.

C4. 2020 On "success" in applied environmental research — What is it, how can it be achieved, and how does one know when it has been achieved?

The article provides a framework for conducting successful applied environmental research. Five key principles include relevance, rigor, collaboration, communication, and environmental and societal impact. Indicators that can be used to measure the success of applied environmental research include:

1) The extent to which stakeholders use research findings to make decisions (can be evaluated by tracking the adoption of research findings in policy documents, management plans, or other decision-making processes)
2) The extent to which the research findings lead to a change in policy or practice (can be evaluated by tracking policy changes, implementation of new practices, or adoption of new technologies resulting from the research)
3) The extent to which the research findings contribute to a better understanding of the environment (can be evaluated by examining the publication of research findings in peer-reviewed journals, citations of the research in subsequent studies, or recognition of the research)
4) The extent to which the research findings contribute to the development of new technologies or solutions (can be evaluated by examining the development of patents, commercialization of technologies, or adoption of new solutions resulting from the research.)

C5. 2020 The evolving treatment of R&D in the U.S. National Economic Accounts

The evolution in the treatment of Research and Development (R&D) in the U.S. national economic accounts is marked by a shift from categorizing R&D as a current expense to recognizing it as a significant investment. The Bureau of Economic Analysis (BEA) initiated the R&D Satellite Account in 1994, aiming to integrate R&D capital into the national accounts. This effort culminated in 2013 with the recognition of R&D expenditures as investments in the core accounts, aligning with international guidelines. The growth accounting model used in the analysis considered R&D as a form of wealth and investment, with the 1994 account providing insights into industry dominance, declining federal funding, and shifts in research types. The 2002 account expanded on this, employing a growth accounting model to assess the impact of R&D on GDP and exploring the returns to R&D capital.

The economic significance of R&D is made quite clear in the article, as expenditures surpass $500 billion by 2015. The breakdown of R&D spending across sectors, including private businesses, nonprofits, and government, underscores the substantial investment in R&D activities. Recognizing R&D as capital since 2013 has reshaped the understanding of economic growth, revealing its substantial contribution and prompting adjustments in GDP figures. The reclassification enhances the understanding of macroeconomic, technology, and tax policy concerns, providing policymakers with improved insights into the nation's saving dynamics and the trade-offs between current and future consumption.

The changes in the national accounts resulting from capitalizing R&D had significant implications, affecting GDP composition, investment, and wealth estimates. R&D investments and capital stocks were considerable, with businesses dominating these activities. The returns to R&D capital, separated into private and spillover components, influenced gross operating surplus, contributing to increases in GDP and GDI. Assumptions about rates of return, deflators, depreciation, and lag structures were crucial in constructing the R&D Satellite Accounts. This comprehensive analysis, spanning the 2006 R&D Satellite Account and subsequent updates, employed a growth accounting model to estimate the contributions of R&D to economic growth, revealing R&D as a significant contributor over the 1961–2000 period, with investment and returns accounting for 2 to 7 percent and 5 to 14 percent of GDP growth, respectively, contingent on alternative assumptions. The introduction of capital services into own-account investment in 2018 further refined the measurement of R&D, considering the return to capital and providing more accurate estimates of investment and savings in the U.S.

In summary, the evolution of the treatment of R&D in the U.S. economic accounts highlights its transformative impact on the Research Level, the Transition and Operational User Benefit Levels, and the Financial Level. At the Research Level, the shift from viewing R&D as a current expense to recognizing it as an investment reflects a commitment to refining estimation methods and addressing methodological challenges. At the Transition and Operational User Benefit Level, the changes in the national accounts resulting from capitalizing R&D have significant implications for GDP composition, investment, and wealth estimates, providing policymakers with improved insights into the nation's saving dynamics and the trade-offs between current and future consumption. At the Financial Level, the economic significance of R&D, as illustrated by expenditures exceeding $500 billion, underscores its substantial contribution to various sectors.

Research Level
• R&D Investment Growth o Measure the growth in R&D investment over time, reflecting increased funding and focus on research activities
• Industry-Specific R&D Contribution o Assess the contribution of R&D investment to GDP growth, particularly in key R&D-intensive industries
• Research expenditure by source o Understand the distribution of research funding which provides insights into the financial sustainability of research initiative. This KPI helps identify the reliance on different funding sources, ensuring a diverse and stable financial base
• R&D Intensity o Measuring R&D intensity as a percentage of total industry revenue or GDP is fundamental for assessing the commitment to research activities related to overall economic output. High R&D intensity often indicates a strong focus on innovation and technological advancement
• Number of patents filed o Key indicator of the quality and quantity of innovations emerging from research efforts. A high number of filed patents suggests a robust innovation pipeline and a strong emphasis on intellectual property creation
Transition and Operational User Benefit Level

• Employment Impact o Monitor the employment impact specifically in industries characterized by high R&D. this reflects the economic and job creation aspects highlighted in the article
• Innovation adoption rate in R&D intensive industries o Evaluate how quickly innovations originating from R&D activities in key industries are adopted. This KPI showcases the practical adoption and impact of innovations
• Customer surveys on product/service quality and innovation o Conduct surveys to gather user feedback on the perceived quality and innovativeness of products or services from R&D intensive industries. Direct user opinions provide insights into tangible benefits required
• GDP Impact o Examine the overall impact on GDP resulting from the recognition of R&D as investment, providing an indicator of the economic benefit
Financial Level
• Time-to-market o The speed at which a product moves from the research phase to being available in the market. A shorter time-to-market can provide a competitive advantage and increase the chances of market acceptances
• Licensing costs / Total R&D costs o Track income from licensing intellectual property - access the success of leveraging research assets with external partners
• Private Fixed Investment in Intellectual Property Products (IPPs) o Track the investment in intellectual property products including software, R&D, and entertainment, literacy, and artistic originals
• Revenue from new products o Reflects the financial impact of successfully bringing research-based products or services to the market. It measures the effectiveness of commercialization efforts in generating tangible returns
• Customer adoption rate o The rate at which customers adopt and embrace new products in the market. High customer adoption rates demonstrate the product's acceptance and market fit
• Return on investment for R&D o Calculating the return on investment for R&D activities which provides insights into the financial effectiveness of the overall commercialization process. It helps evaluate the profitability of converting research into marketable products

C6. 2020 Federal R&D funding: the bedrock of national innovation

This article underscores the historical decline in federal research and development (R&D) funding in the United States, with a focus on key performance indicators at the Research Level. It highlights the diminishing commitment to scientific research by the federal government, tracing the trajectory of R&D funding from its post-World War II growth to its recent stagnation. The decrease in federal R&D intensity as a percentage of GDP serves as a research-level KPI, indicating a deprioritization of research innovation. This decline poses a risk to America's technological leadership and economic prosperity, as other countries outpace the U.S. in crucial research areas, thereby threatening the nation's global standing in technology, economy, and national security.

The article presents Figure 2, reproduced below, illustrating a notable historical shift in R&D funding sources, with the private sector overtaking the federal government. The graphs depict total R&D expenditures by funding source and the percentage of total U.S. R&D funding from different sectors, potentially representing a commercialization-level KPI. These indicators highlight the increasing reliance on private sector funding for R&D activities, emphasizing the need to examine the critical roles of the federal government in guiding national R&D and connecting it to societal needs. The transition from federal to private funding signals a shift in the landscape of research commercialization, with potential implications for the types of research undertaken and their alignment with public priorities.

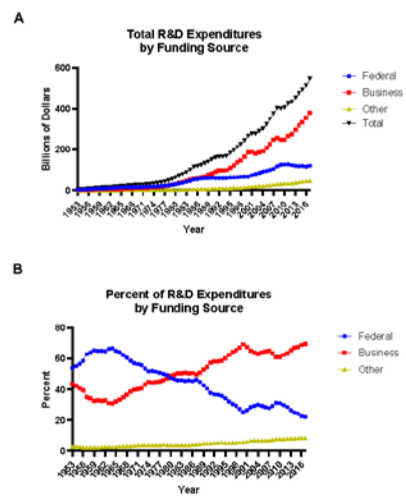


Figure 2: The private sector has overtaken the federal government in research development (R&D) spending. (A) Total R&D expenditures by funding source, in billions of dollars. (B) Percentage of total US R&D funding from the federal government, businesses, and other sources. All amounts are in current U.S. dollars. Source: National Science Board, National Science Foundation, 2020, Research and Development: U.S. Trends and International Comparisons, Science and Engineering Indicators 2020, NSB-2020-3, Alexandria, VA. Available at https://ncses.nsf.gov/pubs/nsb20203/.

The article further explores user benefit-level KPIs by delving into the essential roles played by the federal government in R&D. It introduces a taxonomy of R&D categories, emphasizing the government's critical role in funding research that serves broad public priorities and addressing market failures. The quadrant model proposed by the authors captures the complex relationship between science and technological innovation, considering the intent to generate fundamental knowledge and the practical motivation behind research. This model serves as a user benefit-level KPI, illustrating the nuanced ways federal R&D funding contributes to both scientific progress and the alignment of research with societal needs. The case studies presented, particularly Case study 2 on antibiotic development, exemplify the tangible user benefits resulting from federal intervention in addressing critical societal issues, safeguarding public health, and filling gaps where private industries hesitate.

In conclusion, the article emphasizes key performance indicators at the research, commercialization, and Transition and Operational User Benefit Levels, as shown in Table 2.1 to underscore the importance of federal R&D funding. The decline in federal commitment serves as a research-level KPI, the shift in funding sources is presented as a commercialization-level KPI, and the roles of the federal government in addressing societal needs serve as user benefit-level KPIs. Together, these indicators highlight the multifaceted impact of federal R&D funding on research innovation, commercialization, and user benefits, emphasizing the need for increased public awareness and support for the crucial role played by the federal government in driving scientific progress and addressing societal challenges.

Research Level
● Budget allocation ratio o Assess the distribution of the federal research budget across different areas or disciplines
● Average funding per research are o Calculate the average funding allocated to each research area or discipline
● Average citations per paper o Evaluate the overall impact of federally funded research by calculating the average number of citations per paper
● Collaboration rate o Calculate the level of collaboration by calculating the average number of collaborators per researcher or project
● Patent activity rate o Track the ratio of patent activities including patents issues and invention disclosures
Transition and Operational User Benefit Level
● Technology development index o Evaluate the effectiveness of government intervention in technology development by assessing the number of technological advancements or breakthroughs achieves through targeted funding
● Innovation spillover index o Evaluate the extent to which innovation and knowledge generated from federally funded research spill over into other industries or sectors
● Societal relevance index o Asses the societal relevance of federally funded research by creating an index that combines factors such as environmental impact and contributions to national priorities
Financial Level
● Total R&D expenditures by source o Calculate the percentage of total R&D expenditure contributed by the federal government, private sector, and other funding entities
● Technology transfer rate o Quantify the success of transferring research outcomes to the private sector by calculating the percentage of federally funded technologies adopted by industry partners
● Industry partnership growth

o Measure the growth rate of collaboration and partnerships between academic or federal research institutions and private industries
● Market penetration rate o Gauge the success of commercialized technologies by measuring the rate at which they penetrate the market and gain widespread adoption
● Licensing and royalty efficiency o Assess the efficiency of licensing mechanisms by calculating the ratio of licensing revenue to the overall costs associated with technology transfer

C7. 2020 Identification of KPIs in project-based organizations through the lean approach

This paper underscores the critical need for organizations, especially those operating in complex and globalized environments, to effectively manage their performance. It advocates for the application of lean principles and techniques, emphasizing continuous improvement, waste reduction, and customer value. The research methodology employs a qualitative approach, primarily through a systematic literature review, to identify and categorize Key Performance Indicators (KPIs) specifically tailored to the organizational and operational needs of project-based entities. Lean principles, originating in manufacturing but applicable across diverse industries, are presented as a comprehensive methodology for performance improvement. The DMAIC (Define, Measure, Analyze, Improve, Control) methodology within Lean Six Sigma serves as the framework for creating a lean-based KPI model, aligning project scope with organizational strategy and translating customer and business needs into measurable factors.

The literature review delves into the multifaceted nature of KPIs and their significance in tracking project success and guiding organizational progress. It recognizes the diversity of KPIs and suggests that their selection should be based on criteria such as validity, helpfulness, and relevance. Various KPI categories are discussed, including cost, quality, flexibility, stock, lead time, customer satisfaction, and stakeholder satisfaction. The review also notes the importance of integrating organizational KPIs with operational, life cycle, strategic, and socio-economic aspects. The proposed lean-based model, validated through a case study involving an R&D and innovation project-based organization (CFAA), contributes valuable insights for project-based entities seeking clarity on formulating effective KPIs.

The case study application of the lean-based KPI model to the Centre for Advanced Manufacturing in Aeronautics (CFAA) sheds light on the practical implementation of the proposed framework. CFAA, operating within the University of the Basque Country, focuses on advanced aeronautical manufacturing technologies. The study aims to enhance the measurement of project success in the organization, emphasizing factors related to project management, delivery activities, deliverables, and operations. The study concludes with recommendations for continuous refinement and updating of KPIs in response to changes in the organizational environment. It underscores the importance of validation, communication, reporting, and control mechanisms, with visual management techniques and dashboards being recommended for effective monitoring and control of KPIs. Overall, the research provides a foundation for project-based organizations to enhance their performance measurement strategies, ensuring alignment with organizational objectives and fostering continuous improvement. KPIs are summarized in Table 2.2.

Research Level
● Number of research projects o Measures the quantity of research projects undertaken by the organization
● Success rate of research projects o Calculate the percentage of research projects that achieve their objectives
● Publication impact o Access the impact of research through metrics like citations and publication in high impact journals
● Technology readiness level o Measure the advancement toward practical application
Transition and Operational User Benefit Level
● Customer/User satisfaction o Use survey or feedback to gauge satisfaction levels among end-users or customers
● Adoption rate o Track the rate at which users adopt and utilize the products or services resulting from research
● Social impact measures o Measure the broader societal impact of research outputs on the community or specific groups
Financial Level
● Revenue o Quantify the financial gains from the commercialization of research outputs
● Partnerships and Collaboration o Measure the number and quality of partnerships established with industry
● Time to market o Evaluate the efficiency of transitioning from research to commercial products or services

C8. 2020 Sticky policies, dysfunctional systems: path dependency and the problems of government funding for sciences in the united states

The paper challenges the conventional belief that the decline in American science is solely attributed to inadequate federal funding. It emphasizes the institutional interactions between federal funding agencies and higher education as the root cause. The historical analysis traces the post-World War II development of the U.S. research funding system, highlighting the unintended consequences of institutional rules and norms. The competitive project system, driven by peer review and escalating R&D budgets, led to a massive expansion of university research programs. While successful, this system created an unsustainable demand for federal research funds, outpacing the growth of government budgets. The Research Level key performance indicator (KPI) here is the evaluation of the historical context and the impact of institutional decisions on the research funding landscape.

The paper underscores the transformative change in American science funding post-World War II, particularly the significant role played by the Office of Scientific Research and Development (OSRD) in directing funds to universities. It explores the hybrid system resulting from political compromises, adopting different methods for distributing R&D funds. The focus on individual projects, facilitated by peer review, disrupted traditional funding approaches and institutionalized the influence of the non-governmental scientific community over fund distribution. This inadvertently led to an imbalance in the supply and demand for R&D funds. The Financial Level KPI involves assessing the unintended consequences of the competitive project grant system, its impact on university dynamics, and the resultant challenges in science funding, especially regarding the proliferation of research activities.

The text delves into the consequences of increased federal funding after World War II, which incentivized universities to expand research activities, resulting in a substantial growth in the number of universities offering PhD degrees. While successful in enhancing prestige, this expansion created a demand for research funds that outstripped the available supply. The induced demand, combined with institutional features of American higher education, has led to the current crisis in science funding. The Transition and Operational User Benefit Level KPI involves evaluating the impact of the historical policy decisions on universities, researchers, and the broader science community, emphasizing the challenges faced in securing funding, particularly for early-career scientists. It also raises questions about the sustainability and user benefits of the existing R&D funding system and calls for reform to address these issues effectively.

Research Level
● Grant approval percentage o Percentage of approved research grant applications
● Funding allocation index o Allocation of funds across scientific disciplines
● Annual change in science & engineering PhDs o Changes in the number of science and engineering PhDs granted
● Citation Index o Measures the citation metric and impact of research
Transition and Operational User Benefit Level
● Societal impact score o Assigns a numerical score based on the research's impact on healthcare, technology, and other societal sectors
● Public engagement metrics o Measures public awareness, participation, and interaction with scientific advancements results from federally funded research
● Contributions to societal challenges o Quantifies the extent to which research contributes to solving pressing societal issues, providing a numerical assessment
● Number of success stories o Counts the instances showcasing practical applications and benefits of federally funded research through documented success stories
Financial Level
● Number of Patents and Inventions o Number of patents results from federally funded research
● Industry Collaboration Index o Level of collaboration between universities and industry for technology transfer

● Startup Growth Rate o Increase in startups originating from university research
● Commercial impact o Assessment of how research outputs contribute to

C9. 2019 R&D innovation indicator and its effects on the market: An empirical assessment from a financial perspective

Within the field of innovation management (IM), R&D elasticity is proposed as a measurement for innovation. Since it's challenging to directly measure or quantify the processes involved in innovation, both companies and researchers have turned their attention to measuring innovation inputs and outputs in terms of factors such as spending, brands, licenses, patents, number of new products, and R&D intensity. R&D expenditure is commonly used as a stand-in for innovation, as it enhances the ability to create new products and processes. To enhance the assessment of how efficiently firms utilize their R&D investment, the authors propose considering R&D elasticity, also known as the 'R&D innovation indicator,' as a new metric for understanding innovative activities from a managerial and financial standpoint.

The paper suggests a different way to measure a company's innovation activities, introducing a concept called R&D elasticity. The authors discovered a positive connection between R&D elasticity and how much stakeholders value the company in the market. These findings contribute to ongoing research that aims to create a framework at the policy level, where the R&D elasticity indicator becomes a form of innovation disclosure included in the non-financial information companies release.

This study is the first to look at how various factors influencing innovation affect the value companies create for stakeholders in Innovation Management. It introduces a new way to measure innovation productivity, suggesting it can influence how well companies perform, and it contributes to research in finance and management communication.

For years, research on innovation has mainly centered around its technological aspects. However, it's essential to recognize that innovation spans beyond technology and includes areas like business model innovation, service innovation, and management innovation (MI).

Management Innovation (MI) stands apart from product innovation in certain ways. MI is usually implemented to enhance the efficiency of a company's internal administrative processes, whereas innovations in goods or services are geared towards meeting external demands. Additionally, MI is non-technological, highlighting the crucial role played by the firm's managers in its development and adoption, a role that surpasses that of technicians or researchers.

Under the assumption that R&D is fundamental for innovation, there are various aspects to take into account, including,

1) Traditional accounting metrics at the firm level may not completely capture the shareholder value as perceived by investors. As measuring value creation proves challenging, there is a need for new indicators that can identify the factors contributing to effective financial performance in an environment where multiple stakeholders collaborate.

2) Acknowledging that innovation, driven by investments in Research and Development (R&D), is a critical factor for a company's competitive edge, research on innovation should broaden its focus. It should delve into the organizational processes, specifically exploring the management practices, processes, structures, and tools (referred to collectively as Innovation Management or IM) employed by firms to generate and effectively communicate new ideas, making them successful in the market.
3) From a research standpoint, it's crucial to investigate how stakeholders view the value they derive from information about Research and Development (R&D) released by managers. This exploration is based on the assumption that R&D activities are seen as a potential source of agency problems, creating tensions between insiders (managers) and outsiders (stakeholders).

It is very hard to measure or quantify the processes that incorporate innovation, so the authors propose we consider R&D elasticity as a new metric for innovative activities from a managerial and financial perspective. R&D elasticity (or the 'R&D innovation indicator'), which measures how changes in R&D spending affect other economic factors is proposed as a new metric for innovative productivity from a managerial and financial perspective.

In this methodology, R&D elasticity (or the 'R&D innovation indicator') would be included in a regression model as a factor predicting the market value of firms, or their market capitalization. Consequently, R&D elasticity can be viewed as a tool that management can use to communicate innovation to the market, functioning as a form of voluntary nonfinancial disclosure.

The challenge is to convince those who set accounting standards to update the rules to better reflect the future benefits of innovation. Using an R&D elasticity indicator could be helpful. It would assist in important tasks like figuring out how much profit comes from investing in R&D, assessing the overall benefit to society, and determining a company's true value.

Additional measures of innovation are listed below

Table 1
Measure of innovation.

Measures of innovation	Literature
New products or product improvements	Naranjo-Valencia, Jiménez-Jiménez, and Sanz-Valle (2016)
Patents or patent citations	Jung, Wu, and Chow (2008)
Invention disclosures or suggestions	Axtell, Holman, Unsworth, and Wall (2000); Gu and Li (2003)
Process innovations	Ettlie and Reza (1992); West et al. (2003)
Ratio of sales of new products to total sales	Czarnitzki and Kraft (2004)
Sales force performance and capacity	Wang and Miao (2015)
Ratio of sales of new products to R&D expenditures	Gumusluoglu and Ilsev (2009); Groza, Locander, and Howlett (2016)
Total R&D spending	García-Morales, Matías-Reche, and Hurtado-Torres (2008); Artz, Norman, Hatfield, and Cardinal (2010)
Number of employees in R&D	Calantonea, Cavusgila, and Zhao (2002); García-Morales et al. (2008)
New markets entered	Kanagal (2015), Innovation and product innovation in marketing strategy, Journal of Management and Marketing Research, Volume 18, 1–25; Elenkov and Manev (2009)

C10. 2018 Return of Investment (ROI) in Research and Development (R&D): Towards a framework

This research delves into the intricate relationship between a country's development and its investment in research and development (R&D), with a specific focus on universities as key players in scientific endeavors. While traditional return on investment (ROI) models may be straightforward in industry and service sectors, calculating the ROI of R&D, particularly in universities, is more complex due to the multifaceted nature of scientific outputs. The study proposes a novel R&D ROI model that goes beyond financial considerations, incorporating social impact, organizational and national prestige, and contributions to global knowledge and sustainability.

At the Research Level, the study emphasizes the need to consider not only the financial inputs and outputs but also the social impact and prestige associated with scientific publications. It explores the scientific performance of Tarbiat Modares University (TMU) using scientometric techniques, analyzing factors such as publications, citations, collaboration rates, and faculty performance. The findings suggest a correlation between research expenditure and the number of papers published, with a call to consider broader impacts beyond financial metrics.

At the Transition and Operational User Benefit Level, the proposed ROI model expands beyond traditional metrics by considering factors such as sustainability measures, knowledge and learning, savings in future projects, and skills and competencies. By incorporating these qualitative dimensions, the study advocates for a more comprehensive evaluation of the societal and educational impact of R&D investments. The research concludes by highlighting the importance of formulating a comprehensive ROI model that addresses the heterogeneity of R&D funding sources and objectives in the university setting.

On the financial front, the study introduces a new ROI model (R&DROI) that includes direct returns, social impact, organizational and national prestige, and other qualitative factors. It emphasizes the importance of distinguishing between degrees in assessing ROI, revealing variations in expenditure on research and development across bachelor, master, and Ph.D. programs. This nuanced approach provides insights into the diverse objectives of funding sources, whether from government, social services, or industry, and the need for a comprehensive framework that captures qualitative elements.

Research Level
● Publication output (scientific production) o Number of scientific papers published by the university
● Citation count o Number of citations received by the published papers
● International Collaboration Rate o Percentage of papers co-authored with international researchers
● Research diversity index o Number of different research areas covered in the publications
Transition and Operational User Benefit Level
● Organizational prestige o University's ranking or reputation in global academic rankings
● Societal impact index o Quantitative measure of the societal impact of research outcomes
● Global knowledge contribution o Number of collaborations or contributions that have a global impact
● Knowledge transfer rate o Percentage of research findings that have been successfully transferred to industry or applied in real-world scenarios
Financial Level

• Research and development expenditure o Total expenditure on R&D initiatives
• Expenditure per paper o Average cost incurred for producing a single scientific paper
• Degree-wise expenditure distribution o Percentage of R&D expenditure allocated to different academic degrees
• Innovation index o Number of patents or innovations resulting from R&D activities

C11. 2018 Evaluating firms' R&D performance using best worst method

This study delves into the diverse landscape of Research and Development (R&D) performance assessment, focusing on the measurement of key performance indicators (KPIs) across various organizational levels. Drawing inspiration from Bilderbeek (1999), the research integrates the best worst method (BWM) from multi-criteria decision-making (MCDM) to refine the evaluation of R&D. Aligned with Kaplan and Norton's perspectives (1996), the framework encompasses customer, internal business, innovation and learning, and financial aspects. The BWM introduces variable weights, providing a context-specific approach to R & D assessment and addressing limitations observed in prior studies with uniform measurements. Building on the contributions of Kerssens van Drongelen, Cooke, Bilderbeek, and others, it advocates for a comprehensive approach beyond traditional equal-weighted measurements. The BWM emerges as an efficient tool, enabling nuanced weight assignment for practical and context-specific R&D performance evaluation, overcoming the constraints of uniform assessments.

On the Transition and Operational User Benefit Level, the proposed methodology expands the scope of traditional R&D performance metrics, considering the diverse objectives pursued by firms in measuring success. Through a manager survey, the study collects detailed R&D item-scores, providing insights into specific user objectives like progress monitoring, project profitability evaluation, and researcher motivation. The results highlight the flexibility of the methodology, enabling firms to systematically compare their R&D performance and develop targeted strategies aligned with their distinct goals. This research contributes a comprehensive framework to the ongoing discourse on improving R&D performance measurement and strategic decision-making, offering practical insights tailored to the dynamic objectives of diverse firms in the competitive landscape.

At the Financial Level, the study underscores the significance of innovation and learning as a primary KPI, aligning with the current emphasis on knowledge creation and accelerated innovation cycles. The conceptual framework, adapted from Bilderbeek, delineates four main perspectives—customer, internal business, innovation and learning, and financial—each with distinct sub-criteria. Applying the MCDM methodology to 50 high-tech SMEs in the Netherlands reveals diverse R&D performance rankings influenced by assigned weights. This underscores the critical importance of considering relative importance, offering firms a systematic approach to comparing their performance and strategically positioning themselves in the competitive market. The dynamic nature of the Financial Level, with a focus on innovation and learning, provides a valuable lens for firms aiming to thrive in a rapidly evolving business landscape.

Research Level
• Number of patents

o Indicates the level of innovation and intellectual property generated by the research activities
● Number of ideas/findings o Reflects the creativity and ideation capability of the research team
● Creativity/Innovation Level o Quantifiable measure of the organizations creative and innovative output
● Network Building Activities o Measures the effectiveness of the firm in building networks and collaborations
Transition and Operational User Benefit Level
● Customer satisfaction/market response o A quantitative measure of customer satisfaction and market responsiveness
● Percentage of products succeeding in the market o Reflects the success rate of products in the market
Financial Level
● Expected or realized IRR/ROI o Reflects the financial return on investment, indicating the commercial success of R&D efforts
● Percentage of sales by new products o Demonstrates the market acceptance and success of newly introduced products
● Profit due to R&D o Quantifies the financial gains directly attributable to R&D activities
o Increased market share due to R&D o Indicates the impact of R&D on expanding the organization's market share

C12. 2018 Capturing R&D excellence: indicators, international statistics, and innovative universities

The study introduces a pioneering perspective on evaluating Research and Development (R&D) excellence by defining it as the capacity to produce scientific research that significantly contributes to the development of influential technologies. The methodology involves a meticulous analysis of citations between patents and research publications over a 15-year period, focusing on the top 10% most highly cited patents globally (TopTech patents) and their associated scientific publications (SciTopTech publications). This approach provides a nuanced understanding of the volume of domestic science contributing to patented technologies, revealing substantial variations among countries. Notably, while the USA leads in absolute numbers, accounting for the size of national science systems shows smaller nations such as Switzerland and Israel outperforming the US in generating R&D excellence.

Expanding beyond high-income nations, the study incorporates 70 countries and identifies key factors influencing R&D excellence. The analysis reveals correlations between R&D expenditure, the volume of cited publications, and the degree of university research cooperation with domestic firms. These factors shed light on the commercialization aspect of R&D, emphasizing the importance of financial investment, collaborative efforts between academia and industry, and the overall volume of research output. The findings suggest that a robust R&D ecosystem requires not only significant investment but also effective collaboration between research institutions and businesses, highlighting the commercialization potential of scientific advancements.

The study further delves into an in-depth analysis of 716 research-intensive universities globally, highlighting specific institutions with high scores on R&D excellence indicators. This level of analysis provides insights into the user benefit aspect of R&D excellence, emphasizing the role of universities as key contributors to advanced science-based technologies. The nuanced examination of universities underscores the significance of the availability of human resources and the quality of science systems as crucial factors influencing R&D excellence. This user benefit perspective emphasizes the role of universities in producing knowledge, skilled professionals, and innovative research, contributing not only to technological development but also to broader societal advancements. Overall, the study advocates for a holistic understanding of R&D excellence, considering research outputs, commercialization efforts, and the broader societal benefits facilitated by institutions and nations.

Research Level
● Total research publication o The number of publications indicates research productivity
● Citation impact o R^2 for relationship between variables: the R-squared values indicates a positive or negative relationship between the examined variables
● Innovation concentration o Concentration in high impact areas such as specific fields in high SciTopTech output
● University size and innovation o University size impact: analysis of the innovative capacity of smaller research universities
Transition and Operational User Benefit Level
● Customer satisfaction/market response o Quantitative measure of customer satisfaction and market responsiveness
● Percentage of products succeeding in the market o Reflects the success rate of products derives from R&D activities
● Variation in R&D excellence across countries o Discusses significant differences between high-income and low-income countries
Financial Level
● R&D Excellence scores o R&D Excellence- Absolute: absolute scores measuring overall R&D excellence of universities o R&D Excellence - Relative: relative scores correcting for the size of the universities providing a fair comparison
● Top innovative universities o The top 5 universities are the largest, research-intensive universities in the USA and outside, based on R&D excellence scores
● Industry-relevant R&D expenditure ● Total research expenditure: correlation with R&D excellence, exploring the relationship between R&D spending and excellence

o Industrial research expenditure: correlation with R&D excellence, examining the impact of industry focused research spending
● Global variations in R&D excellence o Differences across countries: highlights variations between high-income and low-income countries

C13. 2016 What Impacts the Performance of Large-Scale Government Projects

The research focuses on identifying six key characteristics for examining large-scale government projects: pursuing non-technical target benefits, long product service life, dealing with multiple stakeholders, large and complex megaprojects, susceptibility to political environment and dynamics, and following a mandated project management process that significantly impacts the performance of large-scale government projects. These characteristics provide a foundation for understanding the challenges and opportunities inherent in government initiatives. For instance, the pursuit of non-financial target benefits underscores the need to align project goals with broader societal objectives, extending the evaluation criteria beyond financial metrics. The research suggests that effective stakeholder management, dealing with multiple stakeholders, and recognizing their influence are crucial elements. These considerations form KPIs for assessing the project's preparedness and potential success, emphasizing the importance of stakeholder engagement as a process.

On the Transition and Operational User Benefit Level, the analysis highlights the distinctive nature of government projects driven by non-financial target benefits and the imperative for long-term product utilization. KPIs include articulating, measuring, and ensuring the attainability of these non-financial target benefits throughout project execution. The extended operational life of government project outcomes, such as infrastructures and information systems, introduces challenges in terms of product design and planning. KPIs for Transition and Operational User Benefit Level involve a managerial focus on non-financial target benefits, emphasizing their articulation, measurement, and attainability throughout the project. Robust product design, effective quality management processes, and a thoughtful technology adoption strategy are proposed as KPIs for addressing the complexities of long-term product utilization in government projects.

At the Financial Level, the research delves into the impact of the political environment on government projects. Aligning projects with current legislation and providing project managers with increased authority emerge as KPIs for navigating politically influenced landscapes. The establishment of cross-organization cooperation and agreements is proposed as a KPI for successful commercialization, particularly in projects involving multiple agencies. The focus on political dynamics underscores the need for adaptability and responsiveness within the project management approach, emphasizing KPIs that enhance alignment with legislation and organization strategies.

Research Level
● Number of projects analyzed in the study o The total count of projects examined in the research, providing an overview of the scale and scope of the study
● Percentage of projects from each country (US, UK, Australia)

o The distribution of projects across different countries, highlighting the geographical diversity and potential variations in project characteristics
● Average project size (in terms of budget or duration) o Calculates the average size of the projects under analysis, either in terms of budget allocated or duration required for completion
Transition and Operational User Benefit Level
● Percentage increase in likelihood of achieving project success by incorporating user focused financial benefits o Measuring the positive impact on project success by considering user-focused non-financial benefits, indicating a user-centric approach to project management.
● Reduction in technology obsolescence and increase the product life o Quantifying the decrease in technology obsolescence and extension of the product life cycle, showcasing the projects' sustainability and adaptability.
Financial Level
● Success rate of projects in achieving non-financial target benefits o Percentage of projects that successfully realized non-financial target benefits
● Number of projects with a focus on technology adoption and maturity tracking o Quantifying the emphasis on technology adoption and maturity tracking, demonstrating the projects adaptability and responsiveness to technological advancements
● Percentage of projects with effective quality management processes o Proportion of projects that implemented robust quality management processes, reflecting the commitment to delivering high-quality outputs

C14. 2016 The EU 2020 innovation indicator: A step forward in measuring innovation outputs and outcomes?

The EU 2020 Innovation Indicator combines four metrics designed to assess innovation outputs and results into a unified measure. These indicators include:

(1) patent applications
(2) the economic significance of knowledge-intensive sectors
(3) the trade performance of knowledge-intensive goods and services
(4) the significance of rapidly growing firms in innovative sectors.

Companies can convert innovation inputs (e.g., R&D, human resources, research infrastructures, and existing knowledge) into intermediate outputs, such as patents, commonly known as throughputs. These throughputs evolve into innovation outputs, such as the number of product and process innovations or the proportion of firms introducing innovations, in a subsequent stage. Assessing innovation outcomes at the industry level offers several advantages compared to evaluating outputs or outcomes at the firm level. One benefit is the ability to capture spillover effects, such as the diffusion of benefits from the innovating firm to other firms, potentially in different industries. However, to accurately gauge innovation outcomes at the national level, it is essential to consider both structural change (reallocating economic activity towards more knowledge-intensive sectors) and structural upgrading (moving closer to the frontier in sectors where countries are already specialized), which the current EU 2020 Innovation Indicator fails to incorporate.

In October 2013, the European Commission introduced a new indicator to gauge how well the EU was advancing toward the objectives of the European Innovation Union flagship initiative. However, recognizing limitations with this indicator, the EC was later asked to develop “a new indicator measuring the share of fast growing innovative companies in the economy” to add an output and outcome dimension to the input dimension already provided by the 2013 R&D intensity indicator.

The revised EU 2020 Innovation Indicator aims to assess innovation outputs and outcomes, serving as a complement to the primary R&D intensity indicator (which measures R&D expenditures as a percentage of GDP) that has been previously utilized for policy coordination.

This article seeks to assess the effectiveness of the recently introduced indicator within the context of challenges associated with measuring innovation outputs and outcomes. A conceptual framework is established to measure innovation outcomes, making a clear distinction between structural change and structural upgrading as distinct dimensions. However, it is noted that the new indicator still leans towards a somewhat "high-tech" interpretation of innovation outcomes.

The EU 2020 Innovation Indicators combines four indicators intended to measure innovation outputs and outcomes into a single indicator: (1) patent applications, (2) economic significance of knowledge-intensive sectors, (3) trade performance of knowledge-intensive goods and services and (4) significance of fast-growing firms in innovative sectors.

Innovation outputs vs. outcomes:
Most attempts to measure R&D innovation in the past have focused mainly on innovation inputs. Although these methods have generally been effective in providing internationally comparable data regarding input aspects, there is still a large gap in obtaining comparable and dependable indicators for innovation outputs and outcomes at the country level.

Companies can convert innovation inputs, including elements like R&D, human resources, research infrastructures, and existing knowledge, initially into intermediate outputs, commonly known as throughputs, such as patents. Next, these throughputs have the potential to transform into direct outcomes of innovative efforts, known as innovation outputs. These outputs usually involve the introduction of innovation to the market (product or marketing innovation) or the improvement of the economic actor's operations (process or organizational innovation). Common metrics for measuring innovation outputs include counts of product and process innovations or the proportion of firms that have implemented innovations.

Innovation outcomes happen after introducing new ideas, and include the economic and non-economic effects on the companies involved. Simply coming up with a new idea or getting a patent doesn't automatically mean there will be immediate economic impacts. These outcomes can also include non-economic benefits, like improved health from new medical equipment.

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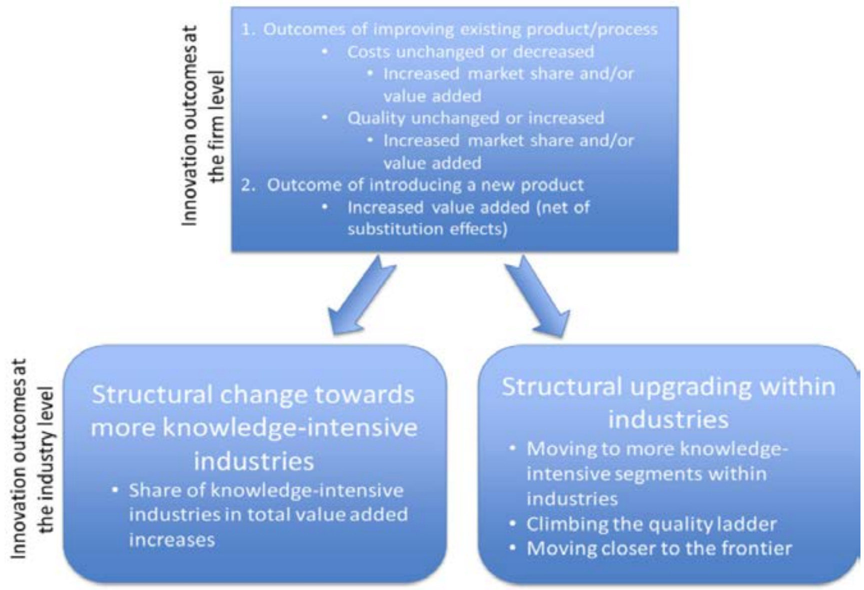


Fig. 1. Innovation outcomes at the firm and the industry level: a conceptual model.

The article notes that the EU 2020 Innovation Indicator adopts a “hightech” view on innovation because the three indicators relating to innovation outcomes (significance of knowledge-intensive sectors, the competitiveness of knowledge-intensive goods and services, and the significance of fast-growing firms in innovative sectors) mainly attempt to measure structural change of economic activity towards predefined sectors with high knowledge intensity.

To adequately measure innovation outcomes at the country level, both structural change (reallocating economic activity towards more knowledge-intensive sectors) and structural upgrading (getting closer to the frontier in sectors countries are already specialized in) should be considered, which the current EU 202 Innovation Indicator doesn’t currently address.

Structural change involves a varying increase in value added across industries, shifting from those with lower knowledge intensity to those with higher intensity. On the other hand, structural upgrading pertains to differing performance levels among firms within industries, without necessarily altering the overall composition of economic activities.

To further their argument, the authors of the paper developed a conceptual framework of innovation outcomes that distinguishes two types of innovation outcomes: (1) structural change towards knowledge-intensive sectors, and (2) structural upgrading/moving closer to the frontier within existing sectors.

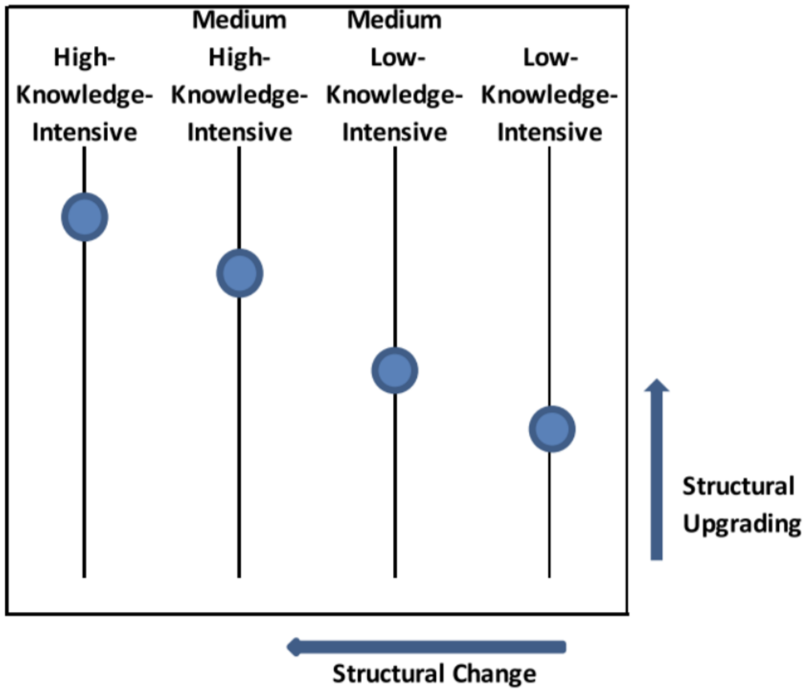


Fig. 2. Schematic display of structural change and upgrading.

Measuring innovation outcomes at the industry level offers several advantages over assessing outputs or outcomes at the firm level. One advantage is the ability to capture spillover effects, which involve the diffusion of benefits from an innovating firm to others, potentially in different industries. A comprehensive framework of structural change and upgrading would, in theory, encompass innovation outcomes from various sources, whether in manufacturing or services, and regardless of the specific type of innovation.

Measuring outcomes instead of outputs also helps address challenges associated with determining the level of novelty in an innovation. From an economic standpoint, the degree of novelty is considered less important than the economic benefits derived from the innovation.

The authors' main takeaway is that when it comes to the economic impacts of innovation, it's not crucial to distinguish too much between radical and incremental innovation (structural change vs. upgrading). However, they emphasize that any indicator aiming to measure outcomes should still include a way to differentiate between structural change and upgrading.

C15. 2015 Success factors of public funded R&D projects

The article comprehensively explores the intricacies of success factors in public-funded research and development (R&D) projects, which play a pivotal role in advancing national scientific and technological capabilities. These projects, primarily undertaken by academic and R&D institutions with government funding, differ from market-oriented endeavors due to their focus on long-term objectives, high intellectual demands, and inherent risks. The multifaceted success factors identified span various categories, encompassing the type of project, leadership and team dynamics, environmental considerations, funding adequacy, management support, collaboration effectiveness, and the inherent difficulty level of the project.

Breaking down these success factors into key performance indicators (KPIs) at the Research Level, the article highlights the significance of clear project goals, research emphasis, and positive group climates. These elements are crucial for measuring the success of the research process itself, ensuring that projects align with organizational vision and contribute meaningfully to the knowledge base. At the Financial Level, KPIs such as funding adequacy, state-of-the-art equipment, and laboratory space come to the forefront. These factors are instrumental in gauging the project's viability for real-world applications and successful technology transfer. Finally, at the Transition and Operational User Benefit Level, effective collaboration, supportive environments, and strategic resource management emerge as KPIs influencing the overall impact and success of R&D initiatives, emphasizing the broader societal and economic benefits derived from these projects.

In summary, the success of public-funded research and development (R&D) projects hinges on a complex interplay of factors, spanning intrinsic project characteristics, resource availability, and internal and external collaboration. Key performance indicators (KPIs) at the Research Level include clear project goals, effective leadership, and a positive group climate, while commercialization success is measured by factors such as adequate funding, state-of-the-art equipment, and organizational support. At the Transition and Operational User Benefit Level, the critical KPIs involve fostering collaboration, creating supportive environments for innovation, and strategically managing resources. The article provides a comprehensive perspective on the multifaceted dynamics influencing R&D success, emphasizing the need for nuanced considerations across research, commercialization, and user benefit domains to maximize the societal and economic impact of these initiatives.

Research Level
● Number of publications o Measure the quantity and quality of research outputs
● Patent filed/granted o Indicates the level of innovation and potential for commercialization
● Technology transfer o Tracks the successful transfer of research findings to practical application
Transition and Operational User Benefit Level
● User adoption rate o Tracks the rate at which users or customers adopt the products/services.
● Customer satisfaction o Measures user satisfaction with the commercialized offerings.
● Impact of industry/community o Assesses the broader impact of the innovations on the industry or community.
Financial Level
● Time to market o Measure how quickly research outcomes are transformed into commercial products or services
● Revenue generated o Evaluates the financial success of commercialized products/services

- Market share
    - o Indicates the competitiveness of the commercialized offerings

C16. 2015 An Empirical Analysis about Technological Development and Innovation Indicators

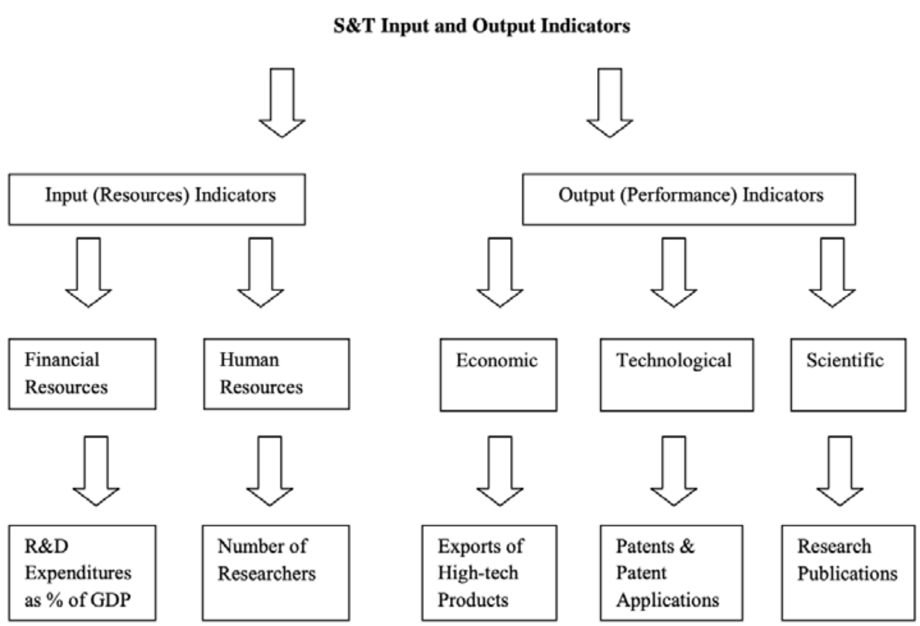
This is a study on the relationship between technological development and innovation indicators and their underlying influence on economic growth, innovation, and national development levels.

Indicators as important proxies for complex concepts. Indicators serve to quantify and understand complex realities like technological development and innovation, which are often difficult to directly measure.

The study utilizes a large dataset spanning 1996 to 2011 and incorporates a wide range of variables, including R&D spending, high-tech exports, patent applications, health expenditure, and internet users.

The study identifies R&D expenditure, patent applications, health expenditure, GDP per capita, female employment in non-agriculture, internet users, and scientific publications as crucial variables significantly impacting technological development and innovation.

Fig. 1. S&T Input and Output Indicators According to the Major Literature



C17. 2014 How to manage your return on investment in innovation

The article discusses the challenges of managing the Return On Investment (ROI) of innovation and outlines four key factors for success. Firstly, it emphasizes the importance of articulating clear objectives in managing ROI. This involves viewing the innovation portfolio through two lenses: realizing ambitions and optimizing value. Realizing ambitions requires setting quantified delivery objectives for different types of innovation, while optimizing value involves a balanced set of portfolio measures.

Secondly, the article underscores the need to clarify accountabilities and governance approaches. It suggests creating cross-functional bodies with sufficient authority to make rapid decisions on resourcing, prioritization, and project approval. The integration of R&D/Technical and Marketing/Brand innovation governance is recommended to enhance value creation through integration and combination. Additionally, the Control/Assurance function is highlighted as playing a crucial role in imposing requirements on business case development, auditing proposals, and helping to resolve disputes.

Finally, the article advocates using consistent logic and matching valuation methodologies with levels of risk and uncertainty across the portfolio. It suggests principles such as a single source of truth, transparency, shared ownership, feedback and learning, and fitness for purpose. The article categorizes valuation approaches based on different growth areas, including core growth areas, adjacent growth areas, and transformational growth areas. Each category requires specific KPIs, such as Net Present Value (NPV) and Internal Rate of Return (IRR) for core growth, risk-adjusted NPV, sensitivity analysis, and decision trees for adjacent growth, and discovery-driven planning, comparables, and multiples for transformational growth.

In summary, effective management of innovation ROI involves clearly defining objectives, establishing robust governance structures, and employing consistent valuation methodologies tailored to the nature of innovation projects. The key performance indicators span research (e.g., NPV, IRR), commercialization (e.g., risk-adjusted NPV, sensitivity analysis), and Transition and Operational User Benefit Levels (e.g., discovery-driven planning, comparables, and multiples).

Research Level
● Research investment efficiency o Measure the effectiveness of research spending in delivering successful outcomes, addressing concerns about the necessity of investment.
● Cross-functional collaboration o Evaluate the extent to which innovation efforts involve cross-functional collaboration beyond traditional R&D activities.
● Breakthrough innovation percentage o Assess the commitment to breakthrough innovation and its proportion in the overall research portfolio.
Transition and Operational User Benefit Level
● User-centric innovation index o Assess the success of innovations in meeting user needs and enhancing overall satisfaction.
● Rapid adoption rate o Evaluate the speed at which users embrace and adopt the innovations.
● Social impact score o Assess and communicate the broader societal benefits and sustainability aspects of the innovation.
Financial Level

● Time-to-market acceleration o Measure improvements in accelerating innovations from the research phase to commercialization.
● Strategic partnership impact o Quantify the impact of strategic collaborations on successful product launches and market performance.
● Portfolio optimization index o Ensure that the portfolio is well-balanced, addressing concerns about poorly optimized innovation project portfolios.

C18. 2013 Critical Factors Towards Successful R&D Projects in Public Research Centers: A Primer

In the context of Research key performance indicators (KPIs), the passage underscores the significance of Public Research Centers (PRCs) in fostering innovation within Latin America, particularly in Mexico. The Triple Helix model, built on interactions among academia, government, and industries, serves as a foundation for innovation. However, challenges such as the lack of competitiveness and inadequate linkages between enterprises and the public sector hinder progress. PRCs, recognized for their potential in high-tech development, face obstacles like the underutilization of self-generated knowledge. The passage identifies 71 factors influencing Research and Development (R&D) projects, emphasizing the importance of planning for technological development within academic institutions. These insights contribute to understanding the research landscape within PRCs, forming crucial Research KPIs.

At the Transition and Operational User Benefit Level of KPIs, the passage further validates the identified factors using the Delphi Method, refining and confirming critical elements for successful R&D projects. Proposals for promoting positive factors and mitigating negative ones are outlined, offering actionable insights for improving the success rate of R&D projects. The emphasis on factors like client interpretation, technology transfer mechanisms, and understanding market dynamics contributes to user benefit KPIs, highlighting the broader societal impact of successful R&D projects. The results not only contribute to technology management within PRCs but also offer valuable insights for decision-makers in enhancing project performance and knowledge transfer initiatives at the Transition and Operational User Benefit Level.

Moving to the Financial Level of KPIs, the passage delves into a methodology to reveal factors contributing to the success of R&D projects within Mexican PRCs. Through a case study involving two PRCs, the study identifies successful and unsuccessful R&D projects and categorizes 71 factors influencing project development. The comprehensive approach, combining qualitative and quantitative methods, culminates in the identification of positive and negative factors affecting project success. Key commercialization KPIs emerge, including factors like strong initial interest from potential clients, robust scientific and technological capacity, and efficient teams. These insights provide a framework for enhancing the commercialization aspects of R&D projects within PRCs.

Research Level
● Number of patents filed and granted

◦ Measures the research center's ability to create and protect intellectual property, indicating innovation and potential for technology transfer.
• Number of collaborative research papers ◦ Indicates the research center's engagement in collaborative efforts, fostering knowledge exchange and partnerships with other institutions.
• Research funding secured per researcher ◦ Evaluates the ability of individual researchers to attract external funding, highlighting their competitiveness in securing financial support.
Transition and Operational User Benefit Level
• User adoption rates ◦ Measures the rate at which end-users adopt and use commercialized solutions, indicating the success and acceptance of implemented projects.
• User feedback conversion rate ◦ Measures the conversion rate of user feedback into actionable improvements, showcasing the responsiveness to user needs.
• Long term user engagement ◦ Evaluates the sustained engagement of users with implemented technologies over an extended period, indicating long-term impact and satisfaction.
Financial Level
• Revenue generated from commercialized projects ◦ Quantifies the financial returns derived from successfully transferring technologies to industries, reflecting commercial viability.
• Number of successful technology transfer partnerships ◦ Quantifies the success of forming partnerships with external entities for the effective transfer of technologies, showcasing collaboration effectiveness.
• Time to market for commercialized products ◦ Measures the speed at which products or technologies are brought to market, reflecting efficiency in the commercialization process.

C19. 2011 Energy R&D portfolio analysis based on climate change mitigation

This article explores the challenges faced by policymakers in optimizing Research and Development (R&D) portfolios for mitigating greenhouse gas emissions within the energy sector. Focusing on the Research Level, the emphasis is on technology valuation, incorporating integrated assessment models that consider both technological and economic factors. Key performance indicators (KPIs) at this stage involve assigning value to technologies based on their emission reduction potential and introducing a likelihood of success criterion through expert assessments. These KPIs offer nuanced insights into the effectiveness of different technologies, combining quantitative measures of emission reduction potential with the qualitative dimension of the likelihood of successful technology development. Policymakers are thus guided in strategically allocating public funds, considering the interplay between technological innovation and economic viability within the broader context of environmental sustainability.

At the Transition and Operational User Benefit Level, the article underscores the importance of adopting pragmatic perspectives that accommodate the limitations of time, expertise, and institutional constraints. The primary objective is to formulate a preliminary yet effective model for an optimal applied energy Research and Development (R&D) investment portfolio. Recognizing the challenges inherent in this process, the article advocates for refinements in methodologies, proposing the utilization of multiple models and sensitivity analyses to augment the precision of technology portfolio evaluations. The key focus is on enhancing the judicious allocation of public resources, particularly in the context of addressing the challenges posed by greenhouse gas emissions. Key performance indicators at this level involve a comprehensive assessment of the overall impact of technological advancements, both in terms of cumulative emission reduction and cost reduction. This approach seeks to provide meaningful insights that can directly inform real-world government budgeting processes, facilitating the allocation of resources toward the most impactful and sustainable R&D initiatives.

Transitioning to the Financial Level, the article delves into the methodologies employed to scale emission reduction values in alignment with the likelihood of success. Two distinct approaches are explored to address this challenge: firstly, a straightforward scaling based on probability and secondly, an innovative method incorporating a probability-dependent time delay in the reduction curve. The latter acknowledges the complex relationship between success likelihood and the temporal aspects of technology deployment. Recognizing the difficulty in representing diminishing success likelihood as an increasing time delay, the article highlights the intricacies involved in quantifying the temporal aspects of technology adoption. At this stage, key performance indicators take the form of assessing the return on investment (ROI) for each incremental level of Research and Development (R&D) investment. This evaluation offers valuable insights into the potential cumulative cost reductions associated with the advancement and successful commercialization of cutting-edge technologies, providing a critical basis for informed decision-making in the allocation of resources and funding.

Research Level
● Number of Advanced Technology Scenarios o Track the variety and number of scenarios explored in the research for assessing the potential impact of advanced technologies on energy systems.
● Research Funding Allocation o Monitor the distribution of research funding among different technology areas, such as transportation, buildings, industry, etc.
● Technology Readiness Levels (TRLs) o Evaluate the progress of technologies by assessing their readiness levels over time, ensuring alignment with deployment goals.
● Intellectual Property Output o Measure the impact of research through the number of patents filed, indicating innovation and potential for technology transfer.
● Collaboration Metrics o Assess the level of collaboration with external partners, industry stakeholders, and other research institutions to enhance knowledge exchange.
Transition and Operational User Benefit Level
● Environmental Impact o Quantify the reduction in carbon emissions, energy consumption, or other environmental benefits resulting from the adoption of advanced technologies.
● Economic Benefits o Track economic indicators, such as cost savings, job creation, and overall economic growth associated with the implementation of advanced technologies.

• Social Benefits o Evaluate improvements in the quality of life, accessibility to clean energy, and other social metrics resulting from the widespread adoption of advanced technologies.
• User Satisfaction and Feedback o Gather user feedback and satisfaction scores to assess the acceptance and effectiveness of implemented technologies.
Financial Level
• Time to Market o Evaluate the speed at which technologies move from the research phase to the commercialization phase, influencing their real-world impact.
• Private Sector Investment o Track the amount of investment attracted from private sectors, indicating industry interest and potential for market viability.
• Number of Startups/Companies Formed o Measure the success of commercialization efforts by monitoring the creation of startups or companies based on the developed technologies.
• Sales and Revenue Generation o Assess the financial success of commercialized technologies by monitoring sales, revenue, and market share.
• Licensing Metrics o Gauge the impact of intellectual property by monitoring licensing agreements and collaborations with industry partners.

C20. 2009 Measuring relative efficiency of government-sponsored R&D projects: A three-stage approach

This study proposes applying a three-stage approach to evaluate Government-Sponsored Projects (GSPs) efficiency, aiming to provide insights for improving the effectiveness of GSP funds. The paper covers input measures, output measures, and external environmental variables of GSPs, introduces the GSP context in Taiwan, explains the three-stage approach, summarizes investigation results, and concludes with empirical implications.

Previous studies on evaluating R&D projects often focused on only one aspect of performance, leading to criticism for not offering a comprehensive assessment of overall R&D success. Furthermore, excessive emphasis on any single indicator distorts assessments of innovation performance. Additionally, past evaluations of government-sponsored R&D projects tended to prioritize outputs over critical inputs like project scope, technical complexity, and staffing, leading to a need for efficiency comparisons (output/input). Addressing these issues requires a more sophisticated method to evaluate efficiency and determine the performance of government-sponsored R&D projects.

Earlier studies on measuring efficiency in operating environments used three approaches: frontier separation, all-in-one, and two-stage methods. These looked at inefficiency differences among Decision-making Units (DMUs) by connecting inefficiency measures to external environment characteristics. However, they couldn't explain how external conditions influenced the efficient use of specific inputs or outputs, which is vital for allocating resources effectively. To address this, a fourth approach, the three-stage method, was introduced.

This study aligns with definitions provided by Georghiou (1999) and Ruegg and Feller (2003). It focuses on practical performance measures, considering both intermediate outputs (like patents and publications) and final outputs (such as enhanced products, processes, and sales). The inputs considered include R&D expenditure, R&D staffing, and post-project period. The study excludes long-term impacts resulting from the interaction between the outputs and the economy or society, such as improved competitiveness or enhanced quality of life.

Note: Georghiou (1999) examined how Government-Sponsored Project (GSP) evaluation works in Europe, identifying different outcomes such as intermediate, final, and long-term impacts. GSP performance is measured through scientific outputs like publications, intermediate outputs like patents and prototypes, and final outputs like new or improved products, processes, or services. Long-term impacts result from the interaction of these outputs with the economy or society. Ruegg and Feller (2003), in a study of the National Institute of Standards and Technology (NIST), proposed dimensions of performance for GSP, including output, outcome, and impact. GSP inputs fund staff administration, with principal outputs being publications, patents, models, and prototypes. Outcomes include sales of new products, productivity effects on firms, and long-term impacts tied to social goals like increasing GDP and improving international competitiveness. External factors affecting GSP performance include firm size, industry type, R&D intensity, technology novelty, and ratio of public subsidy on R&D budget of recipient firms.

A survey involving 110 firms that completed ITDP projects between 1997 and 2005 was conducted. An open-ended questionnaire was used to gather countable input and output measures. To mitigate investigation bias, recipient firms were required to participate annually for 5 years after project completion. Detailed information, such as patent titles and annual profits, was sought for output measures, and input measures were obtained from GSP reports by the MOEA. The table below summarizes measures and operational definitions of key GSP inputs and outputs determined from the survey.

Table 2
Measures of inputs and outputs of GSP.

Dimension	Measures	Items and definition	Reference
Inputs	Project R&D staffing	Number of R&D staffs working in the project	Ruegg and Feller (2003), Revilla et al. (2003), Farris et al. (2006)
	Government subsidy to GSP	Subsidy from the government to GSP in the recipient firm	Ruegg and Feller (2003), Revilla et al. (2003), Farris et al. (2006)
	GSP budget from recipient firm	Budget of the recipient firm invested in GSP	Ruegg and Feller (2003), Revilla et al. (2003), Farris et al. (2006)
	Post-project period	Time lag between the completion of the full project and survey day	Powell and Lellock (2000)
Intermediate outputs	Publication articles	Papers published in journals	Georghiou (1999)
		Papers published in conferences/workshops/seminars	Ruegg and Feller (2003)
	Patent stocks	Patent application Patents granted	Georghiou (1999) Ruegg and Feller (2003), Revilla et al. (2003)
Final outputs	Innovative commercialization	Patents used in product or technology Improved/new technology or products	Georghiou (1999) Ruegg and Feller (2003)
	Profited commercialization	Direct profit from the commercialization of derived technology/product	Georghiou (1999), Linton et al. (2002), Ruegg and Feller (2003), Revilla et al. (2003)

- The study considers four input measures:

- Project R&D Staffing (INPER): This refers to the number of R&D staff working on the project.
- Government Subsidy to GSP (INGOV): This represents the subsidy provided by the government to the GSP in the recipient firm.
- GSP Budget from Recipient Firm (INFIR): INFIR is the budget invested by the recipient firm in the GSP.
- Post-Project Period (INTIME): This denotes the time lag between the completion of the full project and the year 2005.

- Additionally, seven output measures are considered, focusing on the concept of additionality from the GSP, of which the first four are Intermediate output indicators:
  - Number of Patent Applications: The count of patent applications resulting from the GSP.
  - Number of Patents Granted: The count of patents that were granted.
  - Number of Papers Published in Journals: The count of research papers published in journals.
  - Number of Papers Published in Conferences: The count of research papers presented in conferences.
  - Number of Patents Actually Applied in Products or Technologies: The count of patents that were practically applied in products or technologies.
  - Number of Derived Technology or Products: The count of technologies or products derived from the GSP.
  - Profited Commercialization (PCOM): PCOM represents the direct profits from the commercialization of derived technology. It is calculated by multiplying the product profit to contribution ratio, provided annually by the manager of the recipient firm, by the percentage of profits generated from the GSP. PCOM reflects the actual sales of recipient firms' commercialized products resulting from government-sponsored research.

C21. 2007 Managing R&D as A Strategic Option

The article explores the need for a paradigm shift in managing research and development (R&D) by framing it as a strategic option rather than a conventional investment. It delves into the challenges arising from short-term financial perspectives impacting the long-term competitiveness of U.S. industry, especially in R&D management. The prevailing funding models, focusing on Return on Investment (ROI) and similar financial criteria, are criticized for not adequately addressing R&D programs aimed at strategic positioning, which involves reducing technical uncertainties and establishing a robust technical foundation for future profitable investments.

At the Research Level, key performance indicators such as Return on Investment are highlighted as problematic when applied to R&D programs designed for strategic positioning. The article introduces the concept of R&D as a strategic option, drawing parallels with stock options, to better capture the uncertain and long-term nature of technological development. It emphasizes the counterintuitive nature of the value of options compared to traditional investments, particularly regarding volatility and time.

At the Transition and Operational User Benefit Level, the article underscores the significance of identifying strategic objectives and positioning targets for R&D programs. It concludes by emphasizing the need to view technology as a source of global competitive advantage and strategically position corporations with adequate technical strength, even before conventional returns can be established. The concept of creating options for downstream investments is presented as a perspective that aligns with long-term strategic goals, emphasizing the importance of recognizing R&D as a critical driver of future success. By recognizing R&D as a crucial driver of future success and advocating for a proactive stance in technological advancements, the article encourages corporations to not only invest in immediate gains but also strategically position themselves with robust technical strength, fostering sustained competitiveness in an ever-evolving technological landscape.

At the Financial Level, the article underscores the necessity of viewing R&D programs as mechanisms for creating options for future profitable investments. Proposing a multi-stage commitment process, it advocates for incremental exposure at each R&D stage, retaining the option to proceed based on evolving results. Emphasizing the complexities of applying the real options approach, the article highlights the need for ongoing evaluation and exercising of options over time, necessitating adaptable organizational structures. It seeks to reconcile the divergence between the research community's focus on opportunities and corporate management's imperative for resource control, presenting the multi-stage commitment process as a strategic bridge that accommodates both perspectives, optimizing the long-term impact of R&D initiatives on corporate success.

Research Level
● Exploratory Research Investments o Measure the amount invested in early-stage or exploratory research efforts aimed at building knowledge.
● Milestone Achievements o Track progress and success in reaching critical milestones during the R&D process.
● Flexibility and Adaptability o Assess the ability of the research programs to adapt to evolving circumstances and uncertainties.
Transition and Operational User Benefit Level
● Product/Service Quality o Evaluate the quality and performance of products or services resulting from R&D efforts.
● Customer Satisfaction o Assess user satisfaction and feedback regarding the products or services derived from R&D activities.
Financial Level
● Cost Reduction Impact o Evaluate how successful R&D programs contribute to cost reductions in future investments, influencing the exercise price.
● Market Share Growth o Measure the increase in market share attributable to innovations or advancements achieved through R&D.
● Return on Investments (ROI)

o Measure the financial returns generated from successfully commercialized R&D efforts.
● Speed to Market o Assess the time it takes to bring R&D projects to market and their impact on the organization's competitive position.

C22. 2007 R&D and Productivity Growth: A Review of the Literature

The passage delves into the multifaceted relationship between research and development (R&D) and productivity growth, with a particular focus on integrating R&D into national income accounts. At the Research Level, key insights include the necessity of acknowledging spillover effects to comprehensively understand R&D's impact on productivity growth. Seminal studies, such as those by Coe, Helpman, and Hoffmaister (1997), shed light on the positive effects of R&D imports on productivity, especially in developing nations with limited R&D activities. The importance of constructing reliable measures of industry productivity growth in different countries is underscored, emphasizing the need for detailed datasets to capture the nuanced dynamics involved.

At the Transition and Operational User Benefit Level, the passage navigates through the complexities of evaluating R&D returns, focusing on industry studies and their interpretation of private and social returns. It critiques assumptions and highlights the need for careful distinction between industry returns and firm returns. The discussion delves into methodologies for determining R&D stocks on an industry basis, addressing challenges in accurately assigning R&D spending to specific industries. The passage concludes by addressing the international dimension of R&D spillovers, emphasizing their importance in technical progress and the need for statistical agencies worldwide to comprehend and incorporate foreign R&D effects in their economic accounts. This Transition and Operational User Benefit Level analysis recognizes the broader impact of R&D on productivity growth and economic development beyond individual firms or industries.

At the Financial Level, the passage critiques the classification of R&D expenditures as investments, calling for a nuanced approach that distinguishes between privately and publicly financed R&D. It questions the equivalency of treating all R&D spending as equal, highlighting the commercial motivations of private R&D and the differing goals of government and university research. The discussion emphasizes the challenges in accurately measuring indirect returns to R&D and the role of complementary investments in assessing the true economic impact of R&D. This level of analysis recognizes the diverse goals and outcomes of research initiatives across different sectors, urging for a more nuanced classification of R&D expenditures.

Research Level
● R&D Investment Ratio o Measure the proportion of a firm's budget allocated to research and development activities, providing insight into the commitment to innovation.
● Foreign R&D integration index o Evaluate the degree to which a company incorporates foreign research into its R&D processes, highlighting global knowledge integration.
Transition and Operational User Benefit Level
● Productivity growth rate

- Measure the overall increase in productivity over time, indicating the efficiency gains resulting from research and commercialization efforts.
• Customer adoption rate - Evaluate the rate at which end-users adopt and benefit from products or services stemming from R&D activities.
Financial Level
• Technology transfer efficiency - Assess the effectiveness of transferring foreign technologies into the local market, reflecting on the speed and success of commercialization.
• Product market competition index - Gauge the level of competition in the market and its impact on a firm's productivity, as emphasized in the Parente-Prescott and Lewis view.

C23. 2003 Measuring R&D in 2003

The provided text primarily focuses on the evolution of metrics in research and development (R&D) management, spanning four waves of productivity improvement over the past few decades. At the Research Level, the key performance indicators (KPIs) revolved around cost reduction, incremental project improvements, and short-term gains, with a strong emphasis on return on investment (ROI). The mid-1990s marked the shift to the second wave, emphasizing next-generation products and quality improvement, reflected in metrics such as stage-gate processes, global resource utilization, and tracking market share changes.The text underscores how the strategic transition to the second wave not only brought about a focus on next-generation products and quality improvement but also introduced pivotal metrics such as stage-gate processes, global resource utilization, and tracking market share changes, signifying a broader, more nuanced approach to R&D management.

At the Transition and Operational User Benefit Level, the discussion revolves around the transferability of metrics from a quantitative to a qualitative perspective. The text highlights the challenge of assigning value to intangible assets such as patents and personnel, emphasizing the need for adaptable metrics to capture the nuanced nature of qualitative measures effectively. It introduces the innovative idea of extending the application of R&D metrics to measure other intangible assets within the corporate framework, fostering not only consistency across functions but also promoting a holistic understanding of intellectual capital. The conclusion encourages R&D leaders to leverage the rich collection of metrics not just for their department but as a guiding tool for other departments, thereby contributing to a more integrated and strategically aligned organizational framework that enhances overall effectiveness and teamwork.

Moving to the Financial Level, the text underscores the challenges and pressures faced by R&D leaders in responding to Wall Street demands for breakthrough innovation. The third wave introduced metrics that measured the change in a company's market capitalization, emphasizing the impact of R&D on overall business success. This period marked a shift towards quantifying the financial implications of R&D efforts, emphasizing the role of innovation in shaping a company's market value. The fourth wave, triggered by the dot-com crash, brought renewed attention to cost reduction, with metrics evolving to address the need to do less with less and find efficient ways of operating. In navigating these waves, R&D leaders continue to grapple with the dynamic landscape, highlighting the ever-present need for adaptability and strategic evolution to effectively balance innovation, financial considerations, and market demands.

Research Level
● Patents issues (in-process output - lagging - 5 years) o This KPI measures the number of patents granted to the organization within a specific timeframe. A higher number may indicate a robust research output and innovation.
● New products and processes o Quantifies the development of novel products and processes, indicating the organization's capacity for innovation. ● Return on investment o Evaluates the return on investment in R&D activities, providing insights into the financial effectiveness of research efforts.
Transition and Operational User Benefit Level
● Customer Satisfaction index o Measures the satisfaction level of end-users, reflecting the success of R&D in meeting user needs and expectations.
● Product quality rating o Assesses the excellence of products developed through R&D, ensuring they meet high-quality standards and user requirements.
● Innovation adoption rate o Measures how quickly and widely end-users adopt and embrace innovative products or services, indicating their perceived value.
Financial Level
● Commercialization potential o Estimates the potential success of transitioning R&D outcomes into commercial products.
● Strategic alignment o Measures how well R&D activities align with the overall strategic goals of the organization, ensuring that efforts contribute to broader objectives.
● Technology transfer o Tracks the successful transfer of technologies from R&D to practical applications or business units, emphasizing the effectiveness of knowledge transfer.

C24. 1997 The R&D Cycle: The Influence of product and process R&D on Short-Term ROI

This paper explores the complex dynamics governing the relationship between overall research and development (R&D) budgets, with a specific emphasis on the synergy between product and process R&D components. The study, utilizing the PIMS database and employing strategic business units (SBUs) as sampling units, reveals a recurring pattern influenced by the total R&D investment. The research posits three envisioned stages of R&D intensity, spanning from a focus on efficiency to a substantial commitment to R&D. Essential metrics at this level encompass the ratio of process R&D to total R&D, the fluctuating impact of delayed product and process R&D on short-term return on investment (ROI), and the delineation of optimal R&D performance stages.

At the Transition and Operational User Benefit Level, the study provides actionable insights for businesses seeking to optimize R&D for enhanced short-term ROI. It identifies that, at low R&D levels, emphasizing process R&D is beneficial, while at higher levels, a focus on product R&D can lead to diminishing returns. This information empowers companies to tailor their R&D strategies based on their current investment levels, fostering a more strategic and effective approach. The cyclical theory of stages in optimal R&D performance underscores the dynamic nature of the relationship between R&D components and short-term profitability, offering a roadmap for businesses to navigate the complexities of their R&D investments. Key performance indicators here include the potential improvements in short-term ROI through the adjustment of R&D focus based on the identified optimal stages.

The study's findings extend to the commercialization landscape, revealing the impact of R&D components on short-term profitability. The cyclical nature of profit implications from product and process R&D across different stages of R&D intensity emerges as a crucial insight. The optimal R&D performance stages, classified by efficiency, innovation focus, and extensive R&D commitment, highlight strategic directions for businesses. Key performance indicators at this level include adjustments in the percentage of process R&D for companies with extensive R&D and product R&D for companies in the middle stage of spending, thereby offering potential avenues for enhancing R&D productivity. This comprehensive understanding provides businesses with actionable strategies to navigate the complexities of R&D investment and tailor their approaches for maximum commercial impact.

Research Level
● Total R&D (R&D to revenue ratio) o Indicates the commitment of resources to innovation and technological advancement.
● Product R&D/Rev and Process R&D Rev. o Reflects the allocation of resources between product innovation and process efficiency improvements.
● Correlation of R&D with ROI o Captures the relationship between R&D activities and their impact on short-term financial performance.
Transition and Operational User Benefit Level
● Positive or negative correlation signs o Illustrates the changing impact of R&D on short-term profitability as the level of R&D spending varies.
● Customer adoption rate o Evaluates the acceptance and adoption of new products by end-users, demonstrating the practical utility and market fit of the innovations.
Financial Level
● Short-term ROI o Measures the profitability of the business in relation to the R&D efforts, providing an overall performance indicator.
● Two-year lagged product and process R&D with ROI o Indicates the time delay between R&D efforts and their influence on financial returns.

• Time to market for new products o Measures the efficiency of the commercialization process, indicating how quickly innovations are brought to market after research.
• Market share capture rate o Reflects the effectiveness of commercialization efforts in gaining traction and acceptance in the market.

C25. 1997 Measuring R&D Performance State of the Art

The passage primarily discusses R&D performance measurement techniques, highlighting the challenges and considerations associated with choosing appropriate metrics. At the Research Level, the focus is on the development of integrated metrics that combine quantitative and qualitative measures. The author emphasizes the effectiveness of such integrated metrics in providing a comprehensive evaluation of R&D performance, although acknowledging their complexity and cost. Key performance indicators at this level include the comprehensiveness of measurement, the type of R&D, available data, and effort allocation.

At the Transition and Operational User Benefit Level, the passage delves into the use of qualitative, quantitative, and integrated metrics for evaluating R&D performance. It highlights the comprehensive view offered by qualitative metrics at this level, encouraging in-depth assessments. The text suggests that qualitative techniques are suitable for early-stage R&D efforts where quantitative data may be limited. Integrated metrics, combining objective and subjective measures, are presented as a versatile approach that offers a more comprehensive evaluation of R&D effectiveness. Key performance indicators at the Transition and Operational User Benefit Level include the reliability and effectiveness of integrated metrics, their potential for improvement, and the flexibility they provide for assessing different types of R&D efforts. The text underscores the critical role of user-centric metrics in aligning R&D efforts with end-user needs, fostering innovation that directly contributes to enhanced user experiences and satisfaction

Moving to the Financial Level, the text underscores the importance of effective R&D operations for gaining a competitive advantage in the global economy. It points out that R&D effectiveness measurement is challenging due to the newness of the field and the lack of well-defined methods. The discussion revolves around micro-level techniques, categorizing them into quantitative-objective, quantitative-subjective, and qualitative metrics. Key performance indicators at this level include the ease of use and interpretation of quantitative metrics, the suitability of quantitative-subjective metrics for early-stage R&D efforts, and the comprehensive assessment provided by qualitative metrics. Additionally, the text highlights the role of micro-level techniques in addressing the challenges of measuring R&D effectiveness and guiding strategic decision-making in commercialization efforts.

Research Level
• Number of patents generated o Indicates the innovation and intellectual property output from research efforts.
• Number of scientific publications and citations o Reflects the dissemination and impact of research findings in the scientific community.
• Research Expenditures

o Measures the financial investment in research activities.
● Investments in research equipment o Represents the commitment to providing necessary resources for research projects.
Transition and Operational User Benefit Level
● User satisfaction scores o Captures the satisfaction levels of users or customers benefiting from R&D outcomes.
● Numbers of customers or users positively impacted o Quantifies the reach and positive impact on the target audience.
● Metrics related to product performance improvements per R&D dollar invested o Gauges the effectiveness of R&D investments in enhancing product performance.
● Integration of user feedback into assessment o Reflects the responsiveness to user needs and the incorporation of feedback into R&D processes.
Financial Level
● Revenue generated from products introduced o Quantifies the financial success of bringing new products to the market.
● Return on investment or rate of return o Measures the financial performance relative to the investment in R&D.
● Number of new products released o Demonstrates the innovation and successful commercialization of new products.
● Costs reduced through R&D efforts o Highlights efficiency gains and cost-effectiveness achieved through research.

C26. 1996 Applying 'Options Thinking' to R&D Valuation

The article primarily focuses on advocating the adoption of options pricing theory (OPT) in the valuation of research and development (R&D) projects, positioning it as a more insightful alternative to traditional discounted cash flow (DCF) techniques. The key performance indicators at the Research Level involve recognizing situations where OPT and DCF may yield different valuations, understanding computational techniques for options valuation, and highlighting the enhanced insights OPT provides in R&D valuation. Additionally, the criticism of the prevalent use of DCF in the United States and the proposal of "options thinking" as a practical shift in mindset represent critical performance indicators at this level. Ultimately, the article urges R&D managers to adopt OPT, emphasizing its capacity to offer unique insights and valuations that diverge from conventional DCF methods, setting the stage for a more dynamic and adaptable approach to R&D project valuation.

At the Transition and Operational User Benefit Level, the key performance indicators include outlining the implications of adopting an options thinking mindset for R&D planning and strategy. This involves discussing the novel perspective on uncertainty, the recognition that high uncertainty can present opportunities for value creation, and the potential for substantially higher valuations in certain situations. The article also draws a comparison with Japanese companies, emphasizing how the options thinking approach aligns with strategic behaviors observed in successful Japanese firms, especially in terms of a long-term view, rapid market probes, and a focus on growth and market share. The Transition and Operational User Benefit Level highlights the shift in mindset and cultural norms required for Western companies to stay competitive by embracing alternative ways of thinking, such as options thinking.

At the Financial Level, the key performance indicators involve emphasizing the potential competitive disadvantage of relying on DCF, introducing the Black-Scholes formula and the decision tree approach as alternative valuation methods, and providing an illustrative example that highlights the advantages of options thinking over DCF in valuing R&D projects. The article underscores the importance of recognizing managerial flexibility, particularly in the option to abandon projects based on R&D outcomes, and advocates for flexibility and adaptability in R&D investment valuation, setting the stage for the commercialization phase.

Research Level
● R&D spending efficiency o Evaluate the effectiveness of R&D spending by examining the correlation between expenditure and successful research outcomes.
● DCF vs OPT performance o Assess the historical performance of both DCF and OPT in valuing R&D projects, providing insights into their respective contributions.
● Risk management accuracy o Measure the accuracy of risk assessments in different phases, ensuring discount rates align with actual risk levels during research, development, and commercialization.
Transition and Operational User Benefit Level
● Market impact assessment o Measure the market impact of commercialized projects, considering gained market share and overall market growth.
● User satisfaction metrics o Evaluate user satisfaction with R&D outcomes, considering both tangible and intangible benefits perceived by users.
● Market impact assessment o Measure the Market Share Growth (MSG) attributed to commercialized R&D projects, indicating the impact on the organization's presence in the market.
Financial Level
● Success of commercialized projects o Track the success rates of projects post-commercialization, differentiating outcomes between DCF and OPT valuation methods.
● Technology option analysis o Evaluate the maturity and leverage potential of technology options, assessing the effectiveness in mitigating the threat of technology substitution.
● Adaptive decision-making o Monitor the effectiveness of downstream decision points, evaluating the organization's adaptability during the commercialization phase.

C27. 1996 Public R&D policies and cost behavior of the US manufacturing industries

The research investigates the impact of R&D tax incentives and publicly financed R&D investment policies on the growth of output and privately funded R&D in U.S. manufacturing industries. It employs a translog cost function, considering the properties of public goods associated with R&D. The findings reveal that publicly financed R&D induces cost savings but crowds out privately financed R&D. Additionally, R&D tax credits and immediate deductibility provisions significantly influence privately funded R&D. The study emphasizes the importance of evaluating both tax incentives and public financing for effective policy decisions.

Using a dual cost function, the paper estimates the effects of R&D tax policies on privately funded R&D. It distinguishes between R&D performed within and outside the industry, providing a nuanced analysis of spillover effects. Results indicate that R&D tax incentives, particularly the incremental R&D tax credit and immediate deductibility provisions, play a significant role in stimulating private R&D expenditures. The research extends to estimating social benefit-cost ratios of publicly financed R&D and additional privately funded R&D expenditures generated by tax policies. This commercialization-level analysis highlights the role of policy instruments in shaping private sector R&D investment and underscores the need for a balanced approach.

The study explores the intricate relationship between publicly financed R&D, R&D tax policies, and their impact on the cost structure of manufacturing industries. It conducts experiments, assuming changes in government policies, such as abolishing incremental R&D tax credits and increasing publicly financed R&D. While an equiproportional change in R&D tax incentives and publicly financed R&D would lead to an overall reduction in R&D investment, the effects are not uniform across sectors. High-tech industries would face increased after-tax costs, while low-tech industries would benefit. This user benefit-level analysis underscores the complexity of policy interactions, emphasizing distributive effects on different manufacturing sectors. The research advocates for a nuanced approach, suggesting that both subsidies for publicly financed R&D and R&D tax policies are crucial for fostering output growth and productivity, catering to the diverse needs of industries.

Research Level
● Publication Impact o Number of peer-reviewed publications resulting from the research project.
● Collaboration engagement o Level of collaboration with external research institutions or industry partners.
● Innovation index o Number of innovative methods, algorithms, or technologies developed as a result of the research.
Transition and Operational User Benefit Level
● User adoption rate o Percentage increase in the adoption of the developed technologies or solutions.
● User satisfaction o Feedback and satisfaction scores from end-users or customers.
● Real-world impact o Demonstrated impact of the developed technologies in solving real-world problems.
Financial Level

● Patent applications o Number of patent applications filed for technologies developed during the project.
● Industry partnerships o Number of collaborations or partnerships established with commercial entities.
● Funding attraction o Amount of funding attracted from private investors or government grants for commercialization.

C28. 1996 Trends and patterns in research and development expenditures in the United States

The paper extensively analyzes the historical trends and current patterns of research and development (R&D) activities in the United States. Real expenditures on R&D, sourced primarily from the National Science Foundation (NSF), experienced significant growth between the mid-1970s and mid-1980s. In 1995, approximately $171 billion was invested in R&D, with 60% coming from the private sector and 35% from the federal government. The decomposition of total R&D spending by funding source and performer emphasizes the dominant role of the industry, contributing around 60% of funds and executing nearly 70% of the R&D. This detailed breakdown constitutes essential Research KPIs, providing insights into the allocation and utilization of resources in the R&D landscape.

The analysis delves into shifts in R&D funding and performance over time, highlighting the evolving role of the federal government and the private sector. The paper notes a transition from federal dominance in 1970 to industry-funded, industry-performed research emerging as the largest source-performer combination by 1995. The substantial increase in industry spending between 1975 and 1991 raises questions about the economic benefits of this "spending spree." This highlights critical Commercialization KPIs, emphasizing the transformation of research into practical applications and economic value. The study underscores the intricate interplay of economic, policy, and industrial factors shaping the dynamics of R&D expenditure.

The analysis extends to international comparisons, illustrating R&D expenditures as a percentage of GDP for the G-5 countries. The paper acknowledges challenges in determining the optimal level of R&D spending, emphasizing the importance of considering the type of R&D (defense vs. nondefense) and whether it serves as a public good or has spillover effects. The breakdown of government support for academic research by field for G-5 nations in Figure 12 sheds light on divergent national priorities. The U.S. stands out with a significant investment in life sciences, contrasting with the allocation patterns of other G-5 nations. These insights are crucial, indicating the societal impact and alignment of research priorities with the broader goals of academic and national development.

Research Level
● Total R&D Expenditure o Track the total amount spent on research and development in the United States over time, as reported in the article.
● Source of funding distribution

o Monitor the percentage breakdown of R&D funding from different sources, such as private sector, federal government, and other entities, as highlighted in the article.
● Performers share o Analyze the share of R&D performed by different entities, including private firms, federal labs, universities, and other nonprofits, comparing the data between 1970 and 1995 as presented in the article.
Transition and Operational User Benefit Level
● Basic research output o Measure the output of basic research, especially its impact on economic growth and the generation of spillover effects, as discussed in the article.
● Academic research distribution o Examine the distribution of academic research by discipline, considering fields such as life sciences, medical research, and others, as presented in the article.
● Spillover effects o Explore the potential spillover effects of R&D, with a focus on basic research, academic research, and federal lab research, as discussed in the context of economic benefits not captured by the funding entities.
Financial Level
● Industry-funded, industry-performed research o Evaluate the trends and amounts associated with industry-funded and industry-performed research, which is identified as the most substantial source-performer combination in the article.
● Federal funding impact o Assess the impact of federal funding on R&D, considering changes over time and its distribution across performers, as discussed in the article.
● Changes in industry spending o Analyze the changes in industry spending on R&D, particularly the significant increase observed between 1975 and 1991, as mentioned in the article.

C29. 1996 Searching for an effective measure of R&D performance

This paper aims to create a system for assessing R&D effectiveness, considering economic value creation. Measuring R&D performance is challenging due to the nature of activities and reliance on input variables. The authors explore quantitative measures linked to economic value creation and propose a checklist for evaluating R&D projects. They highlight the contribution of R&D to economic value through technological success, R&D efficiency, and integration with manufacturing and marketing. The proposed performance measurement system aims to capture R&D's impact on the firm's future performance.

Measuring the performance of Research and Development (R&D) has always been challenging, mainly due to the nature of R&D activities and the difficulty in pinpointing tangible outputs. Additionally, performance measurement systems have frequently relied on input variables or qualitative assessments of the output, further complicating the process.

Efforts to find quantitative measures of R&D performance, especially those linked to activities controlled by R&D managers, begin with the idea of economic value creation as a firm's goal, and analysis is centered on understanding how R&D contributes to achieving this objective.

Despite various proposed measures, the authors have not pinpointed one that seamlessly integrates with the existing performance measurement system and effectively identifies proxy measures for both the efficiency and effectiveness of Research and Development (R&D).

Traditionally, measurements in the realm of Research and Development (R&D) have been more focused on inputs rather than outputs. This stems from the belief that higher R&D expenses correlate with more effective outcomes. However, there is evidence that this is not always true, as innovative companies are often known to spend less than their competitors. More intricate approaches within the same category examine the extent and proficiency of a firm's R&D capabilities as input variables.

Another approach is the R&D project evaluation procedure that can be used for project selection. A suggested checklist for project evaluation criteria is below:

1) Corporate objectives, strategy, policies and values (criteria measuring the compatibility and consistency of a project with company's strategy and long-range plan)
2) Marketing criteria (including profitability, customer satisfaction, timing, commercial success)
3) R&D criteria (consistency with R&D strategy, technical success, development cost and time)
4) Financial criteria (R&D costs, downstream investments, cash flow profile)
5) Production criteria (manufacturing cost)
6) Environmental and ecological criteria

The impact of R&D on creating economic value can be seen as a blend of two elements: the economic value produced by already specified R&D projects and the value derived from strategic infrastructure.

The performance measurement system proposed by the authors is based on the above consideration and proposes to measure the contribution of R&D projects to economic value creation through measures of:

1) Technological success, which influences future revenues as it may affect customer satisfaction. This measures technological progress as the improvement of a product due to the project evaluated. This measure can be compared with competitors' technical performance and technical progress in a given time span.
2) Efficiency of the R&D function, including both adherence to schedule and R&D productivity. R&D productivity influences cash outflows and adherence to scheduling influences revenues.
    - Adherence to schedule metrics should simply reflect whether, at a certain milestone, time to completion is as planned
    - Measures of productivity describe the resource consumption and ratio of technical success to the amount of resources used such as the ratio of technical progress to costs or the ratio of technical progress to time
3) The degree of integration with the manufacturing function, which influences costs, and the marketing function, which may influence revenues. Examples include,

- Time to market: average concept to launch time, time for each phase (concept, design, initial production, launch)
- Number of redesigns and average time of redesigns
- Design performance (manufacturing cost, manufacturability, testability).

It can be argued that some measures, such as measures of efficiency (including both timeliness and productivity) can be seen as R&D performance. Other measures, such as those of integration, reflect the possibility of R&D to affect future performance of the firm.

C30. 1992 Additional Evidence on the Validity of ROI

This study explores the validity of return on investment (ROI) as a performance measure, especially for firms without publicly traded common stock or divisions within a firm. The primary focus is on assessing the relationship between ROI and stock returns across firms with different types of assets and sizes. Jacobson's (1987) work is extended, utilizing Compustat data from 1967 to 1986. Key performance indicators at the Research Level involve understanding the relationship between ROI and stock returns, considering different asset types and sizes, and assessing the utility of ROI in capturing firm performance for entities with high research and development (R&D) and lower tangible asset investments. Notably, the study contributes valuable insights to the ongoing discourse on performance metrics and their applicability in diverse organizational contexts.

On the Transition and Operational User Benefit Level, the research underscores the importance of ROI accompanied by thoughtful decision-making for managers. The findings suggest that ROI can provide valuable insights, especially for firms with specific characteristics such as high R&D expenditures and mid-size structures. The study implies that while ROI may not be universally applicable, it can offer useful information when tailored to the unique circumstances of different firms. This highlights the nuanced nature of performance measurement and the need for decision-makers to consider multiple factors in their assessments. Additionally, the study emphasizes the user-centric aspect of ROI, indicating that managers can derive meaningful benefits by leveraging ROI in conjunction with informed decision-making processes to enhance their understanding and strategic management of diverse organizational settings.

At the Financial Level, the study delves into the implications of ROI as a performance measure, particularly for multidivisional firms and smaller companies with thinly traded shares. The analysis suggests that ROI may better measure performance for firms with high levels of R&D and mid-size companies. Commercially, the key performance indicators involve the assessment of ROI's relationship with stock returns, recognizing its limitations, and emphasizing the need for wise judgment in decision-making. The study also highlights the ongoing debate around the usefulness of ROI, given its reliance on accounting information rather than market data. Moreover, it underscores the importance of informed decision-making in navigating the complexities of performance evaluation, offering practical insights for commercial strategies in diverse organizational settings.

Research Level
● Correlation between ROI and stock returns o Measure the statistical correlation coefficient between return on investment (ROI) and stock returns across firms with different types of assets and sizes.

• Variation of ROI across asset types and sizes   o Quantify the percentage change in ROI concerning different asset types and sizes, aiming to understand the variation in its applicability.
• Utility index for high R&D and lower tangible asset investments   o Develop an index to measure the utility of ROI in capturing firm performance, specifically for entities with high research and development (R&D) and lower tangible asset investments.
Transition and Operational User Benefit Level
• ROI's contribution with decision-making score   o Develop a score that measures the contribution of ROI when accompanied by thoughtful decision-making processes, providing a quantitative assessment of its importance.
• Value index for specific characteristics   o Create a value index to quantify the insights provided by ROI for firms with specific characteristics, such as high R&D expenditures and mid-size structures.
• User satisfaction score for ROI utilization   o Develop a user satisfaction score based on how well managers derive benefits from leveraging ROI, indicating the level of satisfaction with its application.
Financial Level
• ROI's impact on multidivisional firms   o Quantify the impact of ROI on performance assessment for multidivisional firms by analyzing changes in key financial metrics or market valuation.
• Correlation coefficient between ROI and stock returns   o Calculate the correlation coefficient to assess the strength of the relationship between ROI and stock returns at the Financial Level.
• Index for smaller companies   o Develop an applicability index to measure how well ROI applies to smaller companies with thinly traded shares, emphasizing its suitability for mid-size companies.

C31. 1988 Mitchell - managing RD as a strategic option

The passage addresses the critical issue of the adverse impact of short-range financial perspectives on the long-term competitiveness of U.S. industry, specifically within the realm of research and development (R&D) and technical strategy. The key performance indicators at the Research Level involve the challenges faced by research directors in advocating for long-term R&D projects when traditional financial metrics like Return on Investment (ROI) prioritize short-term gains. The dichotomy between viewing R&D as either a necessary cost of business or an investment further complicates the situation, hindering the exploration of strategic positioning programs that aim to reduce technical uncertainties.

At the Transition and Operational User Benefit Level, the passage underscores the importance of recognizing R&D expenditures as options that create downstream opportunities, ultimately improving the prioritization of impactful and long-term R&D initiatives over short-term gains. The emphasis here is on aligning decision-making responsibility and market perspectives based on the nature of the R&D program—whether it is aimed at knowledge-building, strategic positioning, or business investment. The passage concludes by advocating for a shift in institutional bias towards short-term gains, highlighting the need to strategically position corporations with technical strength in critical areas for sustained competitiveness.

Moving to the Financial Level, the passage introduces an alternative perspective by likening R&D expenditures for strategic positioning to the concept of purchasing options rather than making conventional investments. The focus shifts to the advantages of treating R&D as strategic options, drawing parallels with stock options. At this level, key performance indicators include the potential reduction of future investment costs and the increase in returns resulting from successful R&D programs. The passage suggests that understanding R&D as a strategic option can bridge the gap between business and technical perspectives, encouraging a more nuanced approach to decision-making.

Research Level
● Exploratory research investment efficiency o Measures the effectiveness of investment in exploratory research by evaluating the ratio of the value derived from research outcomes to the cost incurred.
● Strategic positioning potential o Assesses the potential for strategic positioning through focused applied research. It quantifies the ratio of the valuation of strategic options created by research efforts to the cost of conducting strategic positioning research.
● Innovation output ratio o Measures the efficiency of the research process by evaluating the ratio of successfully implemented innovations to the total number of research initiatives.
Transition and Operational User Benefit Level
● Adoption sustainability index o Evaluates the sustainability of technology adoption by measuring the percentage of users who continue to use and benefit from the implemented technologies over an extended period.
● User engagement effectiveness o Assesses the level of user engagement with R&D-driven technologies by evaluating user interactions, feedback, and participation.
Financial Level
● Downstream benefits realization (DBR) o Measures the success of research programs in realizing downstream benefits.
● Cost reduction impact (CRI) o Evaluates the effectiveness of research in reducing costs associated with potential future investments.
● Time to market acceleration o Assesses the speed at which research outcomes are translated into market-ready products or services.

C32. 1988 Brown - measuring R&D productivity

The passage discusses the challenges and importance of measuring Research and Development (R&D) productivity in American industries, especially considering the substantial financial investment involved. It highlights that while $67 billion was spent on R&D in 1988, a significant portion of companies lacked effective measures to evaluate the productivity and return on investment in their R&D operations. The author emphasizes the difficulties in measuring R&D productivity, citing concerns about discouraging creativity, fear of pointing out inadequacies, and past failures in measurement systems. The passage introduces the concept of viewing an R&D lab as a system within the larger organizational framework, explaining the inputs, processing system, outputs, receiving system, and outcomes.

At the Research Level, key performance indicators (KPIs) involve evaluating the R&D lab's inputs, processing system, and outputs. Inputs include people, information, ideas, equipment, facilities, and funds. The processing system encompasses activities like writing proposals, conducting research, and reporting results. Outputs consist of patents, new products, publications, and knowledge. Measuring in-process activities and outputs is discussed as part of internal measurement, with caution against overemphasis on internal measures, which may not reflect the true value of R&D accomplishments.

Moving to the Transition and Operational User Benefit Level, the passage emphasizes the significance of measuring outcomes and outputs that bring value to the organization. The discussion includes examples of companies measuring productivity based on outputs like research proposals, papers published, designs produced, and patents received. The passage criticizes overly complex and subjective measurement systems, advocating for simplicity, objectivity, and a focus on the real-world impact of R&D accomplishments. The ultimate goal is to design a measurement system that not only collects performance data but also guides the R&D program for maximum impact on business results.

Finally, at the Financial Level, the passage underscores the shift in companies pressuring scientists and engineers not only to produce new products and processes but also to demonstrate their value to the organization. The importance of focusing on external measures, outcomes, and outputs is highlighted. Key performance indicators here involve evaluating the tangible impact of R&D on the organization, such as cost reduction, sales improvement, product enhancements, and market share. The passage suggests that an effective measurement system should avoid excessive complexity, subjectivity, and a sole focus on behavior, emphasizing simplicity and objectivity in evaluating R&D performance.

Research Level
● Number of high quality research proposals o Measures the quantity of research initiatives, focusing on proposals that exhibit high-quality criteria.
● Patents granted for innovative research o Assesses the influence and quality of research results by considering the impact factor of publications and citations.
● Research cycle time efficiency o Measures the efficiency of the research process by assessing the time taken from proposal to tangible outputs.
Transition and Operational User Benefit Level
● User satisfaction

o Gauges the satisfaction levels of end-users with the products or processes developed through commercialization.
● Sales improvement o Measures the impact of the commercialized products on overall sales and market performance.
● Cost reduction to end user o Evaluates the extent to which the new products/processes contribute to cost savings for end-users.
Financial Level
● Time to market for new products/processes o Evaluates the speed at which research outcomes are transformed into commercial products or processes.
● Product development cycle time o Measures the time taken to move from the research phase to a finalized, market-ready product or process.
● Cost efficiency o Assesses the economic efficiency of the commercialization process, considering costs associated with bringing products to market.
● ROI o Measures the financial performance of the commercialization process, considering the return on the investment made in R&D.

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