Chapter 1. Assessing the impacts of knowledge transfer on innovation: Channels and challenges

This chapter provides an overview of the different channels of science-industry knowledge transfer, distinguishing the formal ones from the informal. It then presents the methods and data sources that have been used to measure the contributions of public research to innovation, summarising the channels of interaction captured by each approach and outlining the respective advantages and drawbacks of each. The final section discusses the main challenges that arise in assessing the impacts of public research policies on innovation.

Introduction

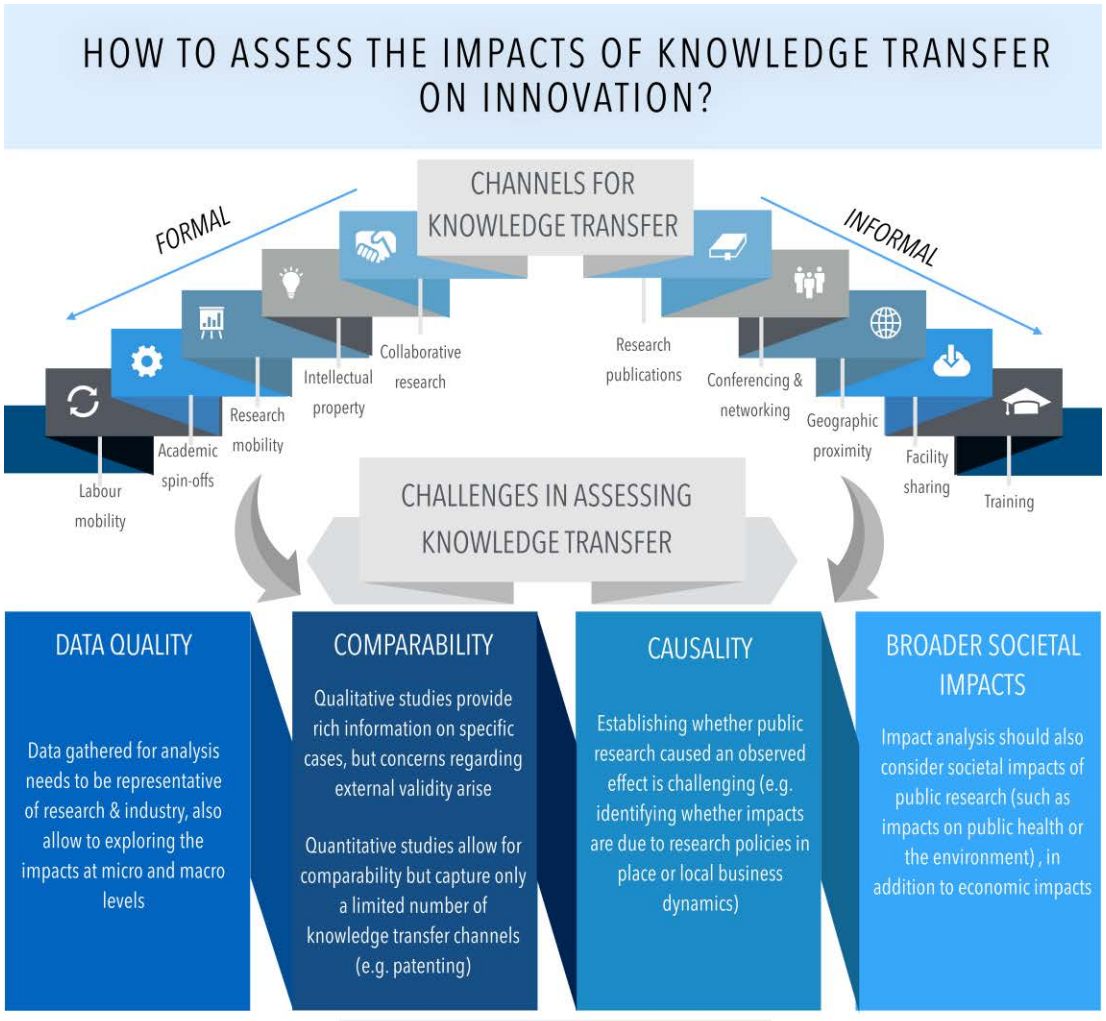
With sizeable public investment in research and mounting budgetary pressures, governments of OECD countries have placed increasing emphasis on enhancing the impact of their investments, specifically concerning their contributions to innovation. Science is a key contributor to building the seeds for innovation and, accordingly, to innovation-driven growth; however, assessing the exact contributions of these investments is a complex process, as the degree of effectiveness is necessarily affected by the efficiency of different knowledge transfer channels in facilitating interactions between industry and science. Accounting for the effectiveness of knowledge transfer is consequently an important but challenging task.

This chapter describes the core channels for knowledge transfer, the methods that have been used to measure impacts, and how these methods perform in tracing the effectiveness of knowledge transfer. The chapter goes on to explain how different methods and sources for measuring knowledge transfer can help shed at least partial light on effective transfer. It also summarises the main challenges in assessing impacts that render effective assessments complex.

The discussion emphasises that this complexity arises from diversity – the very different nature and characteristics of knowledge transfer channels. The limitations of methods to assess this transfer caution against simplistic uses of results. When it comes to assessing impacts, well-known challenges – including causality and limitations to cross-country comparability – need to be taken into account.

The rest of this chapter is structured as follows: Section 1.1 provides an overview of the different channels for science-industry knowledge transfer. Section 1.2 discusses the advantages and disadvantages of the different methods and data sources available to assess the impacts of knowledge transfer. Section 1.3 summarises the main challenges arising for impact assessment. Section 1.4 provides concluding remarks.

Figure 1.1. Synthesis of chapter 1



DATA SOURCES FOR THE ASSESSMENT

	Knowledge transfer channels analyzed	*Advantages*	*Drawbacks*
Publications data	Collaborative research	• Availability of comprehensive, long-term & internationally comparable data	• Industry-research co-publications capture only a small share of collaborative research
Patent data	Collaborative research (co-patenting) & informal linkages (citations to non-patent literature)	• Availability of comprehensive, long-term & internationally comparable data	• Rates of patenting differ across fields • Co-patents only capture a small share of collaborative research
Labour force surveys	Labour mobility	• Representative samples of total labour force conducted regularly across countries • Captures all sciences fields & industry sectors	• Only capture the flow of human capital from university to industry • Sometimes do not allow assessing individuals' contribution to innovation
Surveys & case studies	All channels	• Allow gathering rich information on industry-science relations • Allow studying specific science disciplines & industry sectors	• Costly to implement at large scale • Often confined to specific examples, limiting representativeness

1.1. Channels for knowledge transfer

Science-industry knowledge transfer unfolds through various formal and informal channels (OECD, 2013a; Paunov, Planes-Satorra and Moriguchi, 2017). Formal channels of science-industry interaction are:

a) *Collaborative research* – refers to research projects carried out jointly by public researchers and private firms. It can be fully or partly funded by industry, and can range from small-scale projects to strategic partnerships with multiple stakeholders (i.e. public-private partnerships).

b) *Contract research* – refers to research that a private firm commissions universities or PRIs to perform. It generally involves the creation of new knowledge in line with the specifications or goals of the client, and is frequently more applied than collaborative research.

c) *Academic consultancy* – refers to research and advisory services provided by public researchers to industry clients.

d) *Intellectual property (IP) transactions* – refers to the licensing and selling of IP generated by universities and PRIs to industry.

e) *Research mobility* – refers to both university researchers working in industry and the converse, including temporary assignments.

f) *Academic spin-offs* – refers to the entrepreneurial route to commercialising knowledge developed by public research.

g) *Labour mobility* – refers to university graduates that join industry.

Informal channels of interaction that serve the diffusion of knowledge from research to industry and vice versa include the following:

h) *Publication of public research* in scientific journals and other specialised media.

i) *Conferencing and networking* – interaction between public researchers and industry actors can take place in formal conferences or dissemination events, but also in more informal settings (e.g. meetings of former classmates who are employed in public research and industry sectors).

j) *Networking facilitated by geographic proximity* – that is, informal interactions between public research staff and industry researchers. These might be made easy by, for example, locating science parks near university campuses, or firms' laboratories within university campuses.

k) *Facility sharing* between industry and public research (e.g. laboratories, equipment).

l) *Courses and continuing education* provided by universities to enterprises, and lectures at universities held by industry employees.

Activities (a) to (g) involve specific transactions that can be "traced" (such as signed contract agreements, joint industry-science patents and hiring contracts) and even counted (e.g. the number of academic consultancy contracts, IP licences, or researchers hired). Other channels that drive knowledge transfer, as described in (h) to (l), are not always simple to trace. Informal linkages between faculty members and industry, knowledge exchanges in conferences, and specialised media in particular are difficult to measure, but

important because they allow transferring tacit knowledge that can be critical to innovation.

The importance of different interaction mechanisms varies across science fields and industry sectors (Schartinger et al., 2002). For example, evidence shows that patenting and licensing are very important for researchers in materials science and chemical engineering, but considerably less so for those in computer sciences (Bekkers and Bodas Freitas, 2008). Contract and collaborative research, labour mobility, and the flow of students from university to industry have been found to be very important in engineering disciplines (Meyer-Kramer and Schmoch, 1998; Schartinger et al., 2002; Balconi and Laboranti, 2006); personal contacts, labour mobility and training courses for firms, meanwhile, have comparatively greater relevance in the social sciences (Bekkers and Bodas Freitas, 2008; Schartinger et al., 2002). Breakthrough academic discoveries in biotechnology are in many cases transferred to industry through university spinoffs (Zucker, Darby and Armstrong, 2002).

1.2. Indicators and methods to assess knowledge transfer

As stated above, measuring the impact of public research on innovation is a complex task given the variety of channels through which knowledge transfer unfolds, but also due to the limitations of available indicators. The relative importance of different channels is hard to measure due to difficulties inherent in impact analysis. For instance, outcomes from basic research translate into highly meaningful contributions to industry, but these are difficult to capture as they may only materialise in the long term. That poses a challenge for assessing the impacts of science-industry knowledge transfer.

Contributions of public research to innovation are typically assessed using the following information sources: i) case studies and specially designed surveys; ii) patent data; iii) publication data; and iv) labour force and university graduate surveys. Table 1.1 summarises the channels of interaction captured by each approach, and outlines the advantages and drawbacks of each.

Table 1.1. **Advantages and drawbacks of different data sources and methods to explore science-industry linkages**

Survey data and case studies	
Channels: All	
Advantages	Drawbacks
• Allow gathering rich specific information about industry-science relations, including on the frequency, direction, nature and impact of linkages • Allow specifying scientific disciplines and industry sectors, helping to establish direct linkages • Allow testing for new science-industry linkage dynamics, as framework is openly defined and allows for multiple ways of obtaining information	• Surveys are costly to implement, especially if intended to obtain internationally representative and comparable data • One-off surveys often yield only limited insights on trends • Case studies are often confined to specific examples or scenarios, which limits their representativeness • Survey design needs to account for subjectivity in reporting of existing relationships • The question of the external validity of findings from often small and not necessarily representative samples of the population studied needs to be assessed

Patent data	
Channels: Collaborative and contract research (co-patenting) and informal linkages (citations to non-patent literature, NPL)	
Advantages	Drawbacks
• Availability of comprehensive, long-term and internationally comparable data allows for cross-country analyses, as well as analyses by organisation, region and technology field (OECD, 2009) • Patent citations to NPL and co-patenting enable contributions of scientific disciplines to be identified and quantified	• Rates of patenting across science fields and industry sectors differ, biasing results • Patents are classified by technology and need an additional connection with industry to identify science-industry linkages • Citations to NPL are a "noisy signal" of knowledge flows: few patents cite NPL; citations are frequently given by examiners or by patent attorneys and do not necessarily reflect inputs used by inventors • Citations to NPL do not capture information on the reverse relationship, i.e. contributions of industry to scientific sectors • Co-patents only capture the small share of collaborative research that results in patenting
Publications data	
Channels: Collaborative and contract research (co-publications)	
Advantages	Drawbacks
• Availability of comprehensive, long-term and internationally comparable publications data allows for cross-country analyses, as well as analyses by university, region and scientific field • Number of co-publications allows quantifying outcomes of joint research activities beyond those resulting in patents	• Industry-research co-publications capture only research collaboration that takes the form of peer-reviewed literature; excluded are reports, policy reports, books and other informal collaborations, disadvantaging certain sciences that rely less on co-publications • Publications may be biased towards collaborative "basic" research, while under-representing collaborations that are more applied in nature and do not result in publications • Bias towards publications authored in English disadvantages more locally oriented research • Industry publications represent a very small share of total publications
Labour force and university graduate survey data	
Channels: Labour mobility	
Advantages	Drawbacks
• Labour force surveys (LFS) are representative samples of the total labour force and are conducted regularly across most countries • University graduate (cohort) surveys are representative samples of the population that graduated in a specific year • Allow capturing the contributions of all sciences, including social sciences, to industry innovation	• Do not capture specific channels of science-industry interaction relevant to innovation other than the flow of skilled human capital from university to industry • Not all surveys collect detailed information on particular academic fields of study or sectors of activity • Surveys are generally not comparable across countries, as academic fields of study and industry classifications used differ • Data do not always allow assessing whether human capital contributes to innovation or to other activities, particularly when the level of academic attainment (i.e. bachelor's, master's or doctoral degree) is not specified

Source: Paunov, Planes-Satorra and Moriguchi, 2017.

Traditional data sources and methodologies to assess science-industry linkages capture only a number of specific channels of interaction, and tend to be biased towards certain disciplines and sectors. In particular, informal channels of interaction remain largely uncaptured, as well as service sectors and social sciences disciplines. Moreover, data on other channels of interaction, such as university spin-offs and academic consultancy, are

not collected systematically (except in rare cases), and so only partial information can be obtained. These challenges could be overcome through the development of new indicators and databases, along the lines shown in Box 1.1.

1.3. Main challenges arising for impact assessment

A number of additional challenges to tracing knowledge transfer arise when it comes to assessing the impact of public research on innovation. The CSTP project *Assessing the Impact of State Interventions in Research – Techniques, Issues, and Solutions* pointed to the following important challenges.

(1) Comparability

Qualitative case studies and surveys use tailored questions and methodologies; these allow the analyst to gather rich information on diverse channels of knowledge transfer, including informal channels such as networking and hiring of students. However, qualitative studies – though useful – remain valid only for individual cases, which limits their comparability across cases and countries.

Quantitative studies, on the other hand, are comparable across cases but suffer from limits to the number of impact channels they can trace. The data availability means that formal impact channels, such as patenting and citations of university research, are in focus while others are not.

(2) Causality

The central challenge to any impact analysis is to establish that it is the factor of interest – in this case, public research – that caused the observed effect. In some impact analyses, it is possible to establish causality by estimating the counterfactual situation using a control group (sometimes referred to as a "non-treatment" group). Another approach consists of comparing the behaviour of those being analysed before and after the policy intervention (called "difference-in-difference" estimation). While these concepts are simple in theory, they are both very difficult to capture in practice and difficult to apply to the case of public research. For this reason, the impact analysis conducted as part of the TIP project discussed in Chapter 2 uses an alternative method, building on an instrumental-variable estimation approach.

A related issue is endogeneity, which refers to a situation where there is feedback from the dependent to the independent variable (called "endogeneity"). An example is identification of the geographic proximity of research institutions to local firms, and the effect on the latter's innovation performance and growth. Rather than the presence of research institutions, unobserved local business dynamics such as the presence of leading innovative companies may drive performance.

(3) Collection of micro data and samples

Sampling for impact analysis needs to take into account the distribution of activities and impacts at the micro level. There is agreement in literature that research activity is concentrated among a handful of leading firms and top scientists; the great bulk of top research is produced by a small minority of researchers. In innovation, it is equally well understood that only a very small minority of R&D projects are likely to enjoy commercial success. A random sample of beneficiaries of policy support instruments can

easily miss the few projects that lead to commercial success, leading the evaluator to misjudge the performance of the policy instrument.

An assessment of science-industry knowledge transfer should also account for characteristics of researchers, research institutions, and industry. Leading research teams that produce excellent research may attract more industry funding, while R&D active enterprises are in a better position to apply university research. A related question is how industry and regional characteristics, such as the presence of R&D-intensive industry, clusters of high-tech start-ups, affect science-industry interactions. Better data on the properties of individual researchers, research institutions, and enterprises are key to understanding drivers of knowledge transfer.

(4) Consideration of broader societal impacts

A number of desirable outcomes beyond immediate economic benefits have been neglected in impact analysis, including improved professional skills as a result of policy support instruments aimed at boosting innovation performance. There is also a need for better analysis of the role of students in research impacts, as opposed to education impacts. Moreover, the contributions of public research in addressing societal challenges are not as yet well understood. For instance, decades of investment in public research are at the basis of current developments in the field of AI, a number of which are specifically targeted at tackling social and environmental challenges, such as using AI techniques to improve medical diagnoses, identify illegal fish vessels or optimising food distribution networks in areas facing shortages (Chui et al, 2018).

Box 1.1. **Overcoming challenges to better assess science-industry linkages**

To complement traditional indicators analysed in Table 1.1, use could be made of other data sources that could shed additional light on science-industry linkages. These are the following:

- Data on university-industry contracts, which could allow systematic tracking to establish which industries connect with which academic disciplines.
- Information on publicly funded science-industry collaborative research projects. For example, the European Commission's Community Research and Development Information Service (CORDIS) gathers information about all Horizon 2020 projects. Linkages could be explored by collecting and analysing science and economic data from the academic and industrial partners involved in each project.
- Information on university spin-off activities, which would help identify which science fields generate research for commercialisation. Several countries – including Australia, Finland, France, Korea, the United Kingdom and the United States – have collected such information, frequently at the institutional level. However, such data are often not (as yet) systematically consolidated across institutions, hampering national and cross-country analyses.
- Information from science clusters. While clusters can generate potentially rich information, using it to systematically uncover science-industry relations at the national level may be challenging because of the highly specific contexts of regional clusters.
- Surveys to track labour mobility patterns of doctorate holders, with specific information on academic background and industry field of work, such as the OECD/UNESCO/Eurostat project on the careers and mobility of doctorate holders.
- Surveys to track the labour mobility of professionals in specific science fields, gathered for example by professional associations at the national and international levels.
- Data obtained through web scraping (i.e. the process of automatically extracting information from websites). This technique may offer interesting opportunities for future analyses – for example, if it is implemented to gather systematic information on the skills sought by different industry sectors based on the information contained in their online job offers. The LinkedIn and Monster databases, among others, may offer opportunities in this regard.
- Data obtained through the use of text-mining techniques, often following prior identification of keywords by expert groups. Portugal has experimented with this approach in assessing its research base in strategic priority sectors

Source: Paunov, Planes-Satorra and Moriguchi, 2017.

1.4. Conclusions

Many different methods and data sources are used to measure knowledge transfer, which reflects the complex nature of science-industry interactions and their multidimensional impacts on innovation. The appropriateness of specific data sources and methodologies depends on the objectives of the assessment as well as on the characteristics of the science fields and industry sectors analysed. A multi-method approach combining different data sources and methods will be necessary when the objective is to assess the overall impacts of public research on industry innovation. Another challenge of impact assessment is the comparability of results across countries and industries, and the identification of causal impacts. Results from impact assessment using single methods – including the cross-country exercises described in this report – shed light on specific aspects but not all dimensions of knowledge transfers. Efforts aimed at using new data with the right tools, such as semantic analysis as discussed at the CSTP-TIP workshop *Semantic Analysis for Innovation Policy*, will help improve the knowledge base.

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