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Quantitative Measurement of Innovation Ecosystems: Example Portugal

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Measuring Innovation Ecosystems: Example RTO Portugal

Abstract

The design of efficient and effective innovation ecosystems is crucial to every society, in particular to address structural changes via innovations. We developed a four-quadrant-model to map the established research and innovation landscape with the coordinates Excellence in Science and Excellence in Tech Transfer. The model distinguished between fundamental research, applied research and industrial testing labs. We tested successfully our model in the Portuguese Research & Development (R&D) system by comparison with qualitative interviews.

Introduction

Publicly funded research organizations are crucial for developing innovation ecosystems inside a country. These research organizations are typically local universities providing highly educated and skilled workforce and research originating from the work of these students together with their professors. So, in simple terms, universities generate knowledge from money, and companies generate money from knowledge. This would be the ideal circle in an innovative ecosystem. However, the research originating from universities can very often not be digested by regional companies. For that, there are numerous reasons, such as low technology readiness level TRL, missing product-market-fit of the research output, missing innovative power of regional companies, missing Intellectual Property Rights (IPR) protection, missing certification of the new products etc. Therefore, more players in the innovative ecosystem are needed to promote efficient transfer from ideas to products. There are research transfer organizations and testing labs or certification bodies.

The role of a Research Transfer Organization RTO in the innovation process is to bridge the innovation gap between Technology Readiness Level 2-3 to 6-7, possibly going until 8 facilitating or even entailing the commercialization process when the industry is still missing in the country (Fig.1).

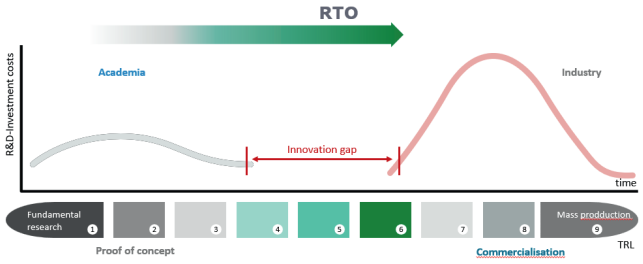

Fig. 1: One-dimensional diagram explaining the role of research transfer organizations (RTO) in the innovation system based on the technology readiness level TRL.

How can one distinguish between the mission of an RTO and the mission of a university? In simple terms, universities are addressing the question "what is the next big thing" whereas the RTO addresses the question "what is the next big deal?". (Fig 2). To fulfil its purpose, the RTO has to deal with fundamental research on the one hand and with markets and innovations on the other hand. Therefore, it needs scientific foresight as well as economic foresight to bridge this gap, aligning emerging research with societal needs and market opportunities.

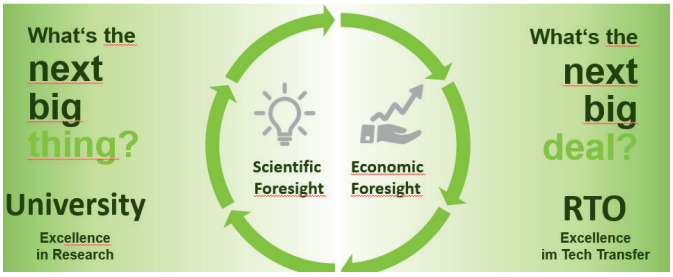

Fig. 2: Schematic diagram to demonstrate that scientific foresight and economic foresight must be synchronized for effective tech transfer.

Both the effectiveness and efficiency of an RTO can be easily monitored on a two-dimensional diagram with the two axes "Excellence in Science" and "Excellence in Tech Transfer" (Fig.3). The exact determination of Excellence in Science and Excellence in Tech Transfer is a matter of debate in literature and intense research has been done on these aspects. We are suggesting in this policy paper a very specific algorithm to calculate the degrees of excellence.

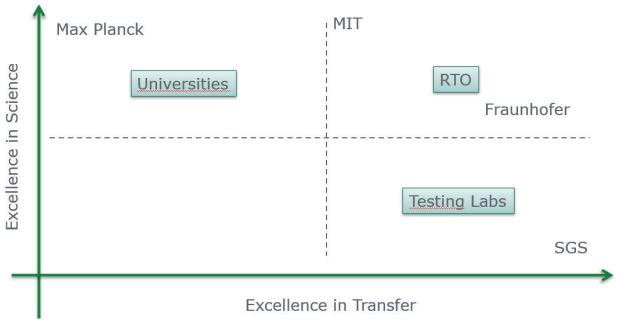

Fig. 3: Two-dimensional schematic diagram with four quadrants to classify universities, Research Transfer Organizations (RTOs) and testing labs or certifying bodies. The x-axis represents the degree of Excellence in Tech Transfer and the y-axis represents the degree of Excellence in Science.

For example, the Max-Planck Society (Germany) has the mission of fundamental research, so according to their mission they are in the top left quadrant. Classical universities would typically have a similar mission in fundamental research. Recently, politicians have encouraged universities to also conduct applied research as part of their new "third mission."
An example of an applied university with Excellence in Science would be MIT (Massachusetts Institute of Technology, USA), being at the border to the top right quadrant. In the top right quadrant, we locate research transfer organizations (RTOs). Their job is to transfer Excellence in Science, in inventions and eventually in innovations. Fraunhofer Society (Germany) is one example. Their institutes score in Excellence in Science not as high as Max-Planck institutes or universities, but are still on a level compatible with fundamental research. The bottom right quadrant is the home of very high-tech-transfer competence combined with low Excellence in Science. These are typically testing labs or certifying bodies such as SGS Germany. They work very closely with industry, helping to quickly bring inventions into the market. Their business model usually includes only a low connection to fundamental research and they are typically private associations or companies. In the lower left quadrant, we localize institutions that have lost either their competence for Excellence in Science or their competence for Excellence in Tech Transfer. They typically need restructuring in order to go back to the other three quadrants, or be closed down.

Methodology

We suggest the following indicators for Excellence in Science and Excellence in Tech Transfer.

Indicators for Excellence in Science

For the quantification of Excellence in Science, we use the accepted categories of the 5P: Publications, Projects, PhDs, Prizes and Patents. Please note that publications, projects and patents are a requirement for Tech Transfer but are not Tech Transfer itself.
In the developed questionnaire, we have broken down the KPIs in 4 different categories:

1. Publications

- Number of Publications by all RTO-Members (as in SCOPUS) per year. It is sufficient that the paper is within SCOPUS with an RTO being one of the affiliations of the paper's authors. This number can be searched by using the RTO affiliation.
- Cumulative number of citations of all RTO-Papers (as in SCOPUS) over the last five years. How to perform: Take all the papers above from e.g. 2019 to 2023 and add all the citations of those papers up until the date of evaluation. For example, Paper 1 from 2019 has 35 citations in Scopus until today, Paper 2 from 2023 has 10 citations until today, so cumulated number is 45 citations.

2. Patents

- Number of Patent-Applications by the RTO-Members per year.

3. Projects

- Number of ERC-Grants per year. These can be ERC starting grants, ERC consolidator grants, ERC synergy grants or ERC advanced grants. We only focused on ERC grants since these are a very good indicator of scientific excellence within Europe.

4. PhD Students

Number of graduated PhD students per year. This can be PhD students supervised by staff members within the RTO, or external PhD students in industry or academia. At least one RTO staff member should be advisor of the PhD student. The year is their year of graduation.

5. Prizes

- Number of prizes for RTO staff members per year with a prize award higher than 10.000 Euro. The prize award can be personal to one researcher of the RTO or institutional to the RTO itself. We chose the high value of 10.000 Euro as threshold to support the criteria for Excellence in Science.

The weighting for the KPI for scientific excellence has been (max. 100 points):

- Publications (max. 30 Points)
- Patents (max. 25 Points)
- Prizes (max. 10 Points)
- PhDs (max. 20 points)
- ERC-Grants (max. 15 points)

Indicators for Excellence in Tech Transfer:

The benchmark of Fraunhofer Society is used to quantify Excellence in Tech Transfer. There are six classical tech transfer paths in this benchmark, one novel path on science communication and one additional criteria to Portugal on scientific employment:

1. contract research via industrial cooperation agreements
2. spin-offs[1] out of the RTO
3. intellectual property transfer via licensing
4. standardization, including standard essential patents
5. transfer over heads including graduates in industry and training courses
6. scientific infrastructure as user facility
7. as a novel category, participation in society via scientific communication
8. as an additional parameter for Portugal, the creation of employment within the RTO is included in Transfer over Heads.

1 Comment: Spin-off is a Start-up that uses either a team of qualified persons from the RTO, or a technology from the RTO or both.

The weighting of those KPIs for Excellence in Tech Transfer has been (max. 100 points):

- Direct industrial contracts (max. 20 Points)
- Collaborative projects with industry (max. 20 Points)
- Patent licensing (max. 10 Points)
- Start-ups (max. 10 Points)
- Standardisation (max. 10 points)
- Creating jobs (max. 15 points)
- Academy for further education (max. 5 points)
- Scientific infrastructure (max. 5 points)
- Scientific communication (max. 5 points)

It is important to note that each of the eight tech transfer paths is used for different tech transfer purposes and depends also on the sectors. For example: Contract research and licensing is mainly for process improvement or product improvement together with an existing industry working in an existing market. It is a classical tech transfer instrument in highly industrialized societies such as Germany, or for established industrial sectors in Portugal. In less industrialized societies, for example, spin-offs combined with standardization or support for Foreign Direct Investments (FDIs) through the use of scientific infrastructure, the transfer of skilled workers, and support with standardization are possible ways for technology transfer.

In conclusion, to determine which Tech Transfer path is relevant for successful technology transfer depends strongly on the degree of industrialization and the active industrial sectors within a country.

Example: Centros de Tecnologia e Inovação in Portugal

Portugal has a broad research infrastructure with about 101 Universities/Polytechnical Institutes, 312 funded Research Units (UID), 31 Centros de Tecnologia e Inovação (CTI) and 34 Collaborative Laboratories (COLAB) in 2025. UIDs are fundamental research centers within universities or polytechnical institutes. They are evaluated by internationally accepted criteria for scientific excellence. CTIs are a group of independent research institutes with legal form of a public association of public interest (PAPI). Their focus should be on applied research.

CTIs carry out research in different industrial sectors, they are between 50 to 3 years old and thus have different regional importance.
The members of these associations are typically the industrial partners of this segment as well as regional universities and regional stakeholders.

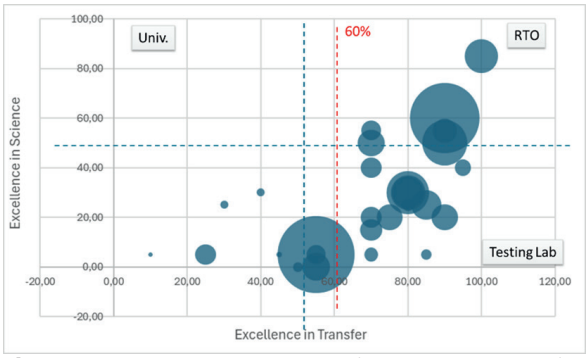

Fig. 4: Four-quadrant-representation of Excellence in Science and Excellence in Tech Transfer for 28 CTIs. The size of the circle represents the relative size of the research unit in full time equivalents (FTE).

The legal structure of an association allows for a legally binding long-term partnership with parties of interest such as industrial partners or universities.
28 CTIs were evaluated quantitatively. Of these 28 CTIs, four were younger than five years. Fig. 4 shows the extracted date in the four-quadrant diagram.
Data analysis provides the following information:

- Of 28 CTI, 12 CTI are above 80% Excellence in Tech Transfer, one Institute has 100%.
- There is no indication that the size correlates with Excellence in Tech Transfer.
- The 12 CTIs with 80% Excellence in Tech Transfer, have an Excellence of Science parameter ranging between 10% and 90%, thus there is at least one CTI with parameters similar to a perfect RTO and another one with parameters like a perfect testing lab.
- Of the 28 CTIs, nine are below 60% Excellence in Tech Transfer.
- 7 CTIs are above 50% in Excellence in Science as well as 50% in Excellence in Tech Transfer and have therefore a character of an RTO.
- 21 CTIs are below 50% in Excellence in Science and are therefore either testing labs
- There is no indication that the size correlates with Excellence in Science.
- There is a correlation between Excellence in Tech Transfer and Excellence in Science.

Discussion

The four-quadrant analysis allows a relevant distinction between different CTIs. It turns out that no CTIs are in the upper left quadrant (the university quadrant), carrying out only good research but have poor tech transfer.
2/3 of the CTIs are in the two right-hand quadrants, being either more RTO-like or more testing-lab-like. For these CTIs, a clear mission is observable from the data. Dependent on their character (testing lab or RTO), financial support through public funding can be precisely allocated to fulfil the mission of the CTI.

For the 9 CTIs that are in the lower left quadrant, a more detailed qualitative analysis is needed to evaluate which mission they are following. From the pure quantitative numbers, they have no clear mission, neither pure research, nor RTO or testing lab.

Within these 9 CTIs, 4 are younger than five years. As mentioned earlier, established organizations often outperform in metrics like publication and patents, creating biases against smaller but maybe more innovative ones. This can be addressed by adjusting the metrics supporting emerging entities and incorporating qualitative assessments of growth and collaboration. Sensitivity analysis of the quantitative data comparing data of three, four and five years shows that the value for Excellence in Science strongly varying over the first years whereas the parameter Excellence in Tech Transfer is more stable. This allows at least to use the parameter Excellence in Tech Transfer to evaluate these units. Since these four CTIs have been initially founded as an association with the focus on tech transfer by a group of industrial and academic partners and an initial business plan, a critical review has to be carried out on their implementation of the tech transfer business plan.

Moreover, looking at Figure 4, there is a correlation between the parameters Excellence in Science and Excellence in Tech Transfer. The reason for this is that the prerequisite for Excellence in Tech Transfer is excellent publications and patents. Thus, being excellent in publications and patents attracts industrial partners und improves the tech transfer parameters. While the two-dimensional framework is useful for classification, it simplifies a complex reality. It overlooks factors such as diversity, sector-specific patterns and changing research or market conditions.

Conclusions

We developed a two-dimensional quantitative model to classify research organizations concerning their Excellence in Science and their Excellence in Tech Transfer. We tested the model for CTIs in Portugal. The model delivers good to very good data quality for research units that are older than 10 years. For younger research units, sensitivity analysis shows that the parameter Excellence in Tech Transfer can be used for research units as young as five years. Our model might help research organizations within their strategy planning as well as funding agencies to allocate conditionally mission-specific basic funding. Furthermore, the model can also help to design funding programs to support mergers of research units, foster collaboration between new and established organizations and guide policies to strengthen innovation ecosystems.

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