



The impact of higher education on innovation: A comparison of Slovenia and Switzerland

Anja Car*, Peter Stanovnik**

*Swiss Nanoscience Institute,
University of Basel,
Klingelberstr. 80, 4056 Basel,
Switzerland
anja.car@unibas.ch

**Institute for Economic
Research, Ljubljana, 1000,
Kardeljeva ploščad 17, Slovenija
stanovnikp@ier.si

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Abstract: Transfer of knowledge between universities and the industrial economic sector and consequently successful innovation process is nowadays an important topic of academic research and a relevant issue for policy makers and technology practitioners in developed and developing countries. In this article we analyse some important research and innovation indicators of performance in systems of higher education in Slovenia and Switzerland and present some relevant comparisons. Switzerland is the leading country on the global innovation index due to its excellent human resources contributing to the high economic, social and environmental welfare. Slovenia is lagging behind innovation leaders in EU. Slovenia has a relatively well developed system of high education. However, it does not achieve above average innovation performance in marketable high value added niche products and services. Our main research question is whether the selected output indicators of Slovenian universities can be compared to the Swiss ones.

Key words: innovation, research, higher education, Slovenia, Switzerland

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Vpliv visokega šolstva na inovativnost: primerjava Slovenije in Švice

Povzetek: Prenos znanja med univerzami in industrijo ter njihov vpliv na inovativnost je dandanes ključna raziskovalna tema tako v ekonomskih študijah kot v politiki znanosti in tehnologijah v številnih razvitih državah in v državah v razvoju. V tem kontekstu smo skušali preučiti vpliv pomembnih kazalnikov visokošolskega izobraževanja in njihov vpliv na trenutno stanje inovativnosti v Sloveniji glede na primerjavo s Švico. Švica je vodilni predstavnik močnih inovatorjev, Slovenija pa zaostaja in sodi v skupino skromnih inovatorjev. Švica je lastnica najvišjega svetovnega indeksa inovativnosti in ta uspeh temelji na človeških virih, ki imajo ustrezna znanja in tako prispevajo k oblikovanju rešitev za izboljšanje življenjskega standarda, okolja in gospodarskega razvoja. Glede na to, da so najmočnejši atributi Slovenije prav tako človeški viri, bi morala biti Slovenija država, ki je prepoznavna po inovativnih in visoko tehnološko usmerjenih podjetjih v izbranih nišah na svetovnem trgu. Osnovno raziskovalno vprašanje je bilo ali se lahko Slovenija po izbranih kazalnikih odličnosti visokošolskega sistema primerja s Švico.

Ključne besede: inovacije, raziskovanje, visoko šolstvo, Slovenija, Švica

1 INTRODUCTION

Throughout human history, innovations have been of utmost importance not only for the prosperity but sometimes even for the survival of entire civilizations. Innovation can be defined as the implementation of a new or significantly improved product, service, process, new marketing ideas or new organizational methods in business practices, workplace organization, etc. Research and development (R&D) provide new knowledge and approaches, leading to improvements and better efficiency in existing processes. It is widely recognized that there is a need to strengthen cooperation between industry and research institutions in order to meet the growing demand for innovation in the global market. Knowledge transfer between universities and industry is a key research topic in both economic and management studies, as well as in the science and technology policy agenda of many developed and developing countries (De Wit-de Vries et.al., 2019).

Successful economies are based on strong research, knowledge transfers and innovation. Unfortunately, Slovenia has difficulty reaching the innovative level of established EU members. Compared to the EU-27 countries, Slovenia has recently invested modestly in R&D. With regard to R&D expenditure intensity (Figure 1), Slovenia began to gradually approach the EU countries by 2010 but since 2016 the gap has not narrowed. On average, 2.07% of GDP was allocated to research in the EU member states in 2017, whereas Slovenia reached the lowest point at 1.86% in that year and remains below the European average. Slovenia and all other EU countries are far behind Switzerland, which in recent years allocates more than 3% of GDP to R&D. In Figure 1, the dash -line shows the trend of GDP development for the period 2011-2019.

According to Eurostat, data are available for the years 2011, 2015, 2017 and 2019 and are marked with crosses. The path from research to the realization of innovations generally requires a series of activities, e.g. financial investments covering a wide range, from the purchase of new equipment and software, investments for acquiring external knowledge, training and investments for introducing innovations to the market, etc. (Strengthening the Innovation Ecosystem in Slovenia, 2021). Here, we should also not forget other important factors, such as a favourable climate conducive to the development of ideas supported by state institutions and the promotion of an innovation culture through the education process (Stanovnik, Uršič, 2019).

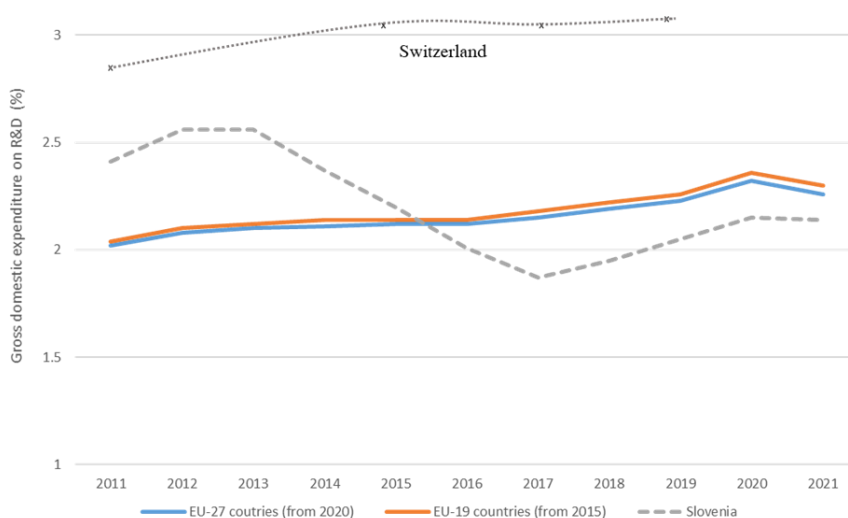


Figure 1: Gross Domestic Expenditure on research and development in % of GDP in Switzerland, Slovenia and EU27 in the period 2011-2021
Source: adapted from Eurostat (2023)

In general, European countries have strong systems of higher education, research infrastructure and research output but they fail to translate this into market innovation at the same speed as the USA or, as in the last two decades, China. Several reasons have been suggested for the current state of affairs, and one relates to the fact that European universities are less connected to industry, so research is less adapted to practical use (Goldfarb & Henrekson, 2003). The lack of technological hotspots such as Silicon Valley and the lower availability of venture capital in Europe compared to the USA is also seen as an important element for successful academic entrepreneurship (Siegel idr., 2007).

The European community has implemented a series of initiatives that try to imitate the US model of an academic entrepreneurship. Given its relevance and complexity, promoting the commercialization of science has become a central feature of government and university policy in most European countries today (Perkmann idr., 2013). However, it is necessary to emphasize that there is a need for greater clarity regarding the purpose and goals of entrepreneurial education, which is also a problem in Slovenia. These should be based on a broadly defined set of multiplier effects (involvement in international business networks, strategic alliances, the flow of researchers from universities to companies and vice versa, prevention of brain drain, etc.) and not only on a narrow measurement of the number of start-ups created at universities. Entrepreneurial education is about developing attitudes, behaviour and abilities at the individual level and about using those skills during an individual's career to create a series of long-term benefits for society and the economy. For Europe, in order to be able to progress on a socio-economic, political, educational and cultural level, taking into account the increasing globalization, it is crucial to encourage creativity and cooperation between different social actors. Creativity, entrepreneurial skills, risk-taking adaptability and innovative ability, problem-solving skills, effective teamwork, interdisciplinary exchange of information and knowledge are key advantages to succeed in competitive environment (Bothwell et al., 2008, pp. 169-186).

To make the best out of this potential, it is essential that educational institutions and non-formal learning methods empower the young generation with those skills from an early stage of learning. Such an approach encourages a multi-perspective view of the challenges and possible solutions, thus helping to develop creativity. Teaching young people with sound for innovation and entrepreneurship, including social entrepreneurship, is particularly important for building more inclusive and advanced societies that provide opportunities for all, including people from less privileged backgrounds. One of the prerequisites for generating high-quality innovative content is the ability to reach a certain level of knowledge (Jones, 2009).

Like innovation, education is a cumulative process, and access to knowledge depends on access to basic education and skills early in life. Education alone probably cannot make someone a great innovator but it is definitely necessary for potential innovators to acquire a certain level of knowledge. To this end, we can generalize that education develops cognitive and non-cognitive skills that have a beneficial effect on personal development. In an attempt to create a mapping between higher education, research and innovation, Biasi and Ma (Biasi & Ma, 2020) connect higher education and university`s programs with academic publications and patents. They show large differences between and within institutions. The universities that respond quickly enough to changes and update the content of subjects perform the best. This research work certainly shows that educational institutions with a modern approach and high quality of lecturers/mentors also have strong impact on the promotion of innovation.

2 RESEARCH METHODOLOGY

This paper focuses on the comparison of selected indicators in two high-education systems (Switzerland and Slovenia) and their impact on innovation. Switzerland represents an example strong innovator at the global level and Slovenia a group of modest innovators. (European Innovation Scoreboard, 2022). For the past few years, Switzerland has been on top of the global innovation index (Global Innovation Index, 2022) This success is based on human resources that have the appropriate knowledge and are thus able to contribute to the creation of solutions to improve living standards, the environment and also contribute to economic development. Given that Slovenia's strongest attributes are also based on human resources, Slovenia should also be a country that is recognized for its innovative and highly technologically oriented companies in selected niches on the global market. In this context, we want to examine what role higher education plays in the current state of the innovation processes.

The methodological approach of this work is based on statistical analysis of various secondary data related to research, development and innovation at university levels in Switzerland and Slovenia. For Swiss higher education system there were included into research the following universities (Table 1):

Table 1: The list of Swiss public universities

Universities in Switzerland
University of Basel (Unibas)
University of Bern (UBe)
University of Fribourg (UFr)
University of Geneva (Uge)
University of Neuchâtel
University of Lausanne (Ulus)
University of Lucerne
University of Lugano
University of St. Gallen (USG)
University of Zurich (UZu)
Swiss Federal Institute of Technology Lausanne (EPFL)
Swiss Federal Institute of Technology Zurich (ETH)

For the examination of Slovenian higher education system there were included public universities: University of Ljubljana, University of Maribor, Primorska university and partially Institut Jožef Stefan as the leading research and educational institution.

Secondary data for the research were collected through various websites, databases and technology transfer offices. The data are based on the number of published professional/scientific articles, patents/patent applications and created companies (startups, spin-offs) in the last 5 years. (2017-2021). The empirical research part is based on a quantitative method of collecting secondary data and a combination of their analysis and synthesis. Access to certain data (repository databases of scientific publications) and data was not possible because they do not exist or are incomplete. This especially applies to the universities of Neuchâtel, Lucerne and Lugano. For this reason, the data of the mentioned universities are not included in the data analysis (highlighted in table1)

Data on the number of scientific articles and patents were comprehensively collected for all Slovenian universities via the unified Cobiss database. Some data are also included for the

Jožef Stefan Institute as the leading research and high educational institution. Although this is not a public university, it is a public research institute with exceptional scientific weight on Slovenian and global scale. Data on created (startup/spin-off) at the University of Maribor and the University of Ljubljana were provided by the knowledge transfer office of the University of Ljubljana. Data for the University of Primorska were not available to us.

3 COMPARISON OF SLOVENIAN AND SWISS UNIVERSITIES' RESEARCH AND INNOVATION PERFORMANCE

Switzerland offers favourable structural, political and socio-cultural conditions for science and research. It offers a high degree of academic freedom, an international scientific staff, high federal and private sector investments in science and a wide range of public funding opportunities. For a small country, it hosts a large number of higher education institutions, such as the world-renowned Swiss Institute of Technology in Zurich (ETH Zurich) and in Lausanne (EPFL), famous research universities such as those in Basel, Bern, Geneva, Lausanne and Zurich, as well as other higher education institutions for applied sciences, for teacher education and higher education institutes for the arts. In addition, the country hosts large research centers of global, national and regional importance, such as the Organization for Nuclear Research (CERN) or the Swiss Federal Laboratories for Testing and Materials Research (EMPA). These favourable conditions have a beneficial effect on the research environment, were Switzerland presents one of the most innovative countries in the world.

Slovenia is actively involved in the Bologna process and, as a member of the European Union, is committed to the goals of the Lisbon strategy. The goal of higher education is to establish high-quality, diverse, accessible and internationally comparable tertiary education. Among the most important goals of tertiary education are quality, employability and mobility in Europe and the world, fair access, as well as the diversity of institutions and study programs. The Swiss education system is one of the most advanced in the world (Education in Switzerland, 2020). The administration and regulation of the school system in Switzerland are carried out by the cantons, while the central government provides the general educational framework. Each canton determines its own school calendar, curriculum and assessment criteria. A special feature of the Swiss education system is that it takes into account the wishes and abilities of pupils in primary and secondary schools. This attribute is achieved by diversifying courses that can be chosen during the education process. Considerable emphasis is on languages and science. Switzerland ranks among the best in the world when it comes to higher education (Swiss higher education system, 2022).

There are 12 public universities, and one private, 8 public higher education institutions (Fachhochschule or Höhere Fachschule) for applied sciences. The difference between a University and a Fachhochschule is that the latter generally does not award a doctoral degree. A Fachhochschule also differs from a traditional Swiss university in its practical teaching as opposed to the university's more theoretical orientation.

It is widely accepted that patents are the driving force in innovation obtained through R&D. Universities' involvement in patenting can also be problematic if the patents are limiting the degree of scientific knowledge. Many researchers have expressed concern about the impact of patenting on the university's traditional mission of disseminating knowledge, enabling basic research and academic freedom. When universities deal with patents, they expect a financial incentive that will continue to drive their research. These hopes stem from the exclusive property rights (IP) that patents provide. The companies, often request exclusive licenses because they offer more protection for the necessary development into a marketable product. Opponents of academic patenting argue that patent protection in the university system imposes high social costs in terms of limited use of technology and

monopoly pricing of technology. With the focus on academic patenting, research may become increasingly driven by economic incentives rather than academic curiosity. Under this influence, researchers may focus on the research that has the greatest financial potential. On this point, we must emphasize that it is usually a long way from an invention to patent application/registration and to innovation. It is essential that universities establish a balance between motivations and incentives for basic research and incentives for patenting and cooperation involving universities as institutions, individual researchers, and potential patent beneficiaries who assume risks for the success of patent commercialization. R&D expenditure and investment is a long-term focused cost and an important determinant of operational and market performance. They will only be reimbursed, if the inventions also become successful on the market. Institutions must balance a long-term frame with the prospect of generating a positive return on investment. A good indicator of innovation and quality of education is a comparison of the ranking of universities with innovative positioning on the university ranking scale (University Rankings, 2022).

The following data provide a quick overview of academic performance in recent years. Research classification refers to the scope, impact and quality of an institution's research output. Figure 2 shows differences in research and innovation performance of 3 Swiss high educational institutions (ETH, University Zurich, Ecole Polytechnique Lausanne) and 3 Slovenian universities (Univerza v Ljubljani, Univerza v Mariboru, Primorska univerza). The research ranking refers to the volume, impact and quality of the institution's research output. The innovation ranking is calculated on the number of patent applications of the institution and the citations that its research output receives from patents.

We see the results of excellence in terms of conducted research and innovation in recent years for selected Swiss universities and all three Slovenian universities. The good news is that all Slovenian public universities are showing growth in terms of research excellence. For 2022, University of Ljubljana even shows values that compare favourably with University of Zürich and EPFL. Despite the good positioning of Slovenian universities in the research ranking, e.g. University of Ljubljana is on 119th in relation to innovation the ranking is much lower (212th place). In comparison, ETH is ranked 42nd in research excellence and on 45th place in innovation. Clearly, ETH is highly positioned, both in terms of research and innovation. Similar conclusions can be made for other universities. For Slovenian universities, a backsliding of innovation can be observed between 2017-2021. One could speculate, that this phenomenon is a result of a sharp reduction in R&D investments by the state in the years 2016-2020 (Figure 1).

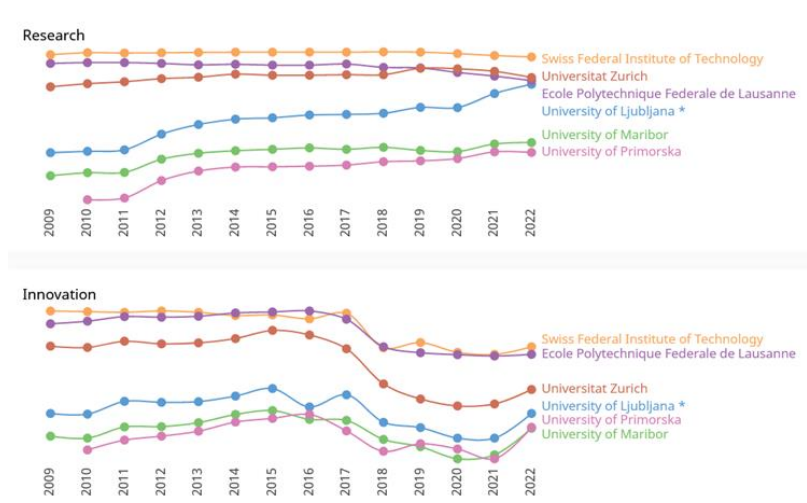


Figure 2: Ranking of universities based on research performance and innovation excellence
Source: University rankings, 2022

In order to support the thesis that Slovenian higher education institutions provide education comparable to the education obtained within the Swiss higher education (Drnovšek, Uršič, Stanovnik, 2022), we collected relevant data pertaining to the public universities in Switzerland and Slovenia (Car, 2022). Fachhochschulen are not included in the analysis, because we do not have a comparative equivalent in the Slovenian education system. In Slovenia, such programs are integrated within the universities and do not exist as separate institutions. We also excluded most research institutes from this analysis, in order to make the data comparison more relevant.

Figure 3 shows the average number of scientific publications per researcher per year for the 2017-2021 period. The gap between the average value for Slovenian and Swiss universities is surprisingly small. A researcher at a Slovenian university publishes on average 0.8 scientific articles per year. The value for a Swiss researcher is 0.97, which is some 20% higher. In the data where the IJS is included, the values for Swiss (0.97) and Slovenian (0.99) researchers are practically the same.

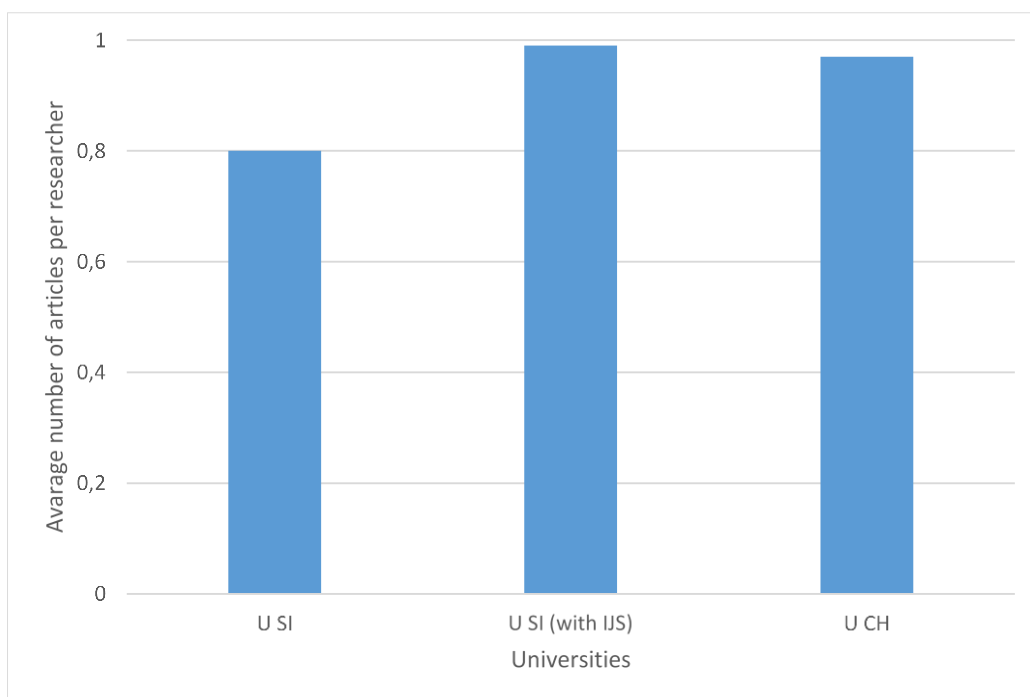


Figure 3: Comparison of the average number of scientific articles published per researcher at all Slovenian (including IJS) and Swiss universities in the 2017-2021 period
Source: own calculation based on (Car, 2022)

Figure 3 shows an insight into the publications output in the last 5 years, where the average value of scientific articles per researcher is shown taking into account of all publications at Swiss and Slovenian universities. The first two columns represent Slovenian output of scientific papers (the first one without Institute Jožef Stefan), the third column Swiss average number of scientific papers per researcher.

If we compare the average number of patents per researcher (Figure 4) at Slovenian and Swiss universities for the period 2017-2022, we even see that Slovenian universities with a value of 0.009 exceed Swiss universities (0.006). After including the IJS data (0.012), this value is twice as high as the average value shown for Switzerland. We have to emphasize that these results represent only a quantitative comparison and based on them we cannot draw conclusions on the quality and impact of the innovations that these patents potentially

bring. However, these figures do indicate that the entire Slovenian higher educational system is capable of training researchers to levels comparable to Swiss ones.

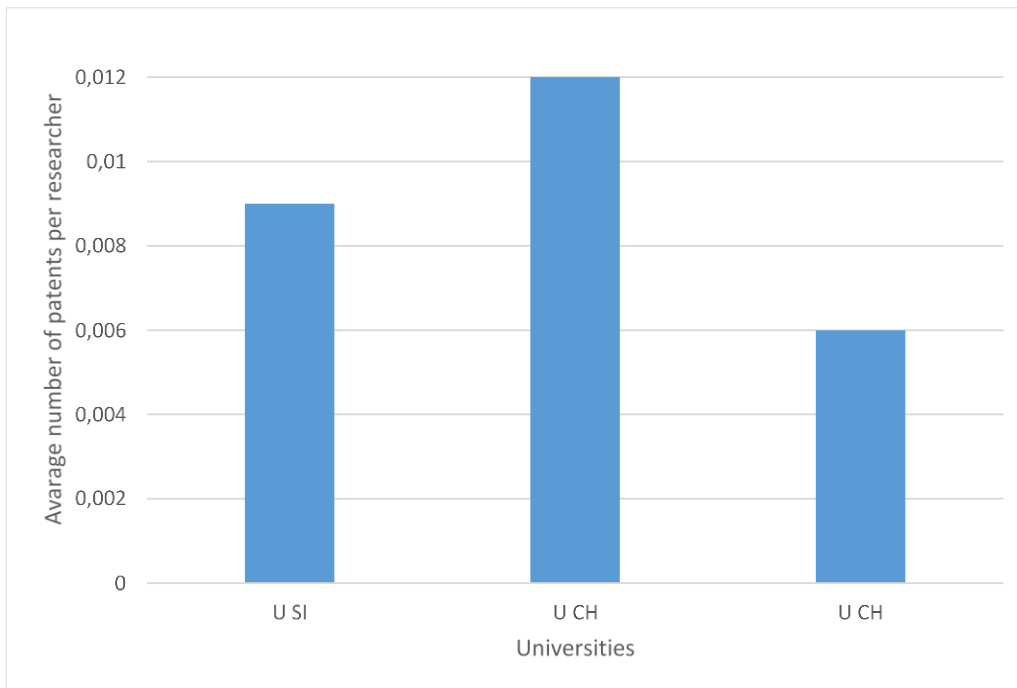


Figure 4: Average number of patents per researcher at Slovenian (including IJS) and Swiss universities in 2017-2021 period
Source: own calculation based on (Car, 2022)

Data on newly created companies as a result of university research similarly show higher values for Slovenia. Figure 5 shows the average startup/spin-off per researcher at Slovenian and Swiss universities for the period 2017-2021. From the plot, we can see that Slovenian universities with a value of 0.005 significantly exceed Swiss universities (0.002). These indicators show a different positioning of Slovenia as compared to indicators of research excellence and innovation performance (Figure 2), where Swiss universities display higher values than Slovenian universities.

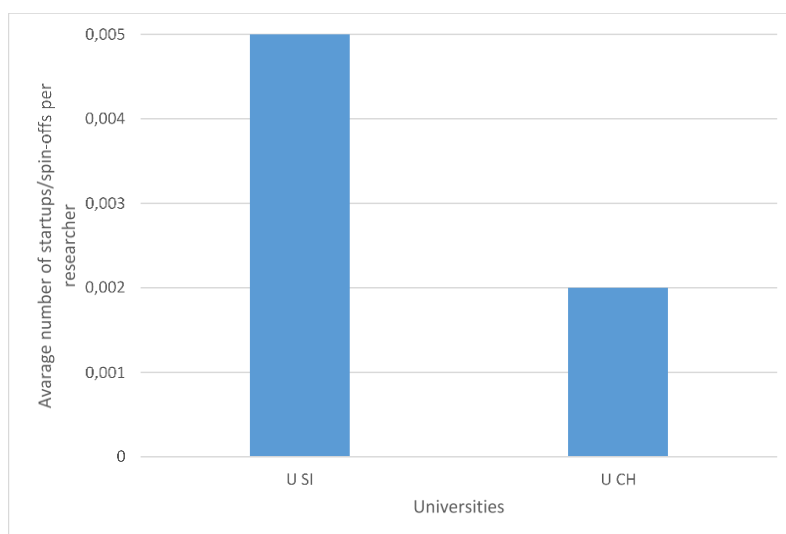


Figure 5: Average number of startups/spin-offs per researcher at Slovenian and Swiss universities in the 2017-2021 period
Source : own calculation based on (Car, 2022)

The transition from the idea to the invention/innovation phase is usually a mixture of conceptualization and implementation design. (Likar et. al., 2006) The aim is to generate enough details to decide on the feasibility and market potential of the idea. The transition from invention to innovation, in addition to finalizing the technical details, also means to develop and promote the economic efficiency of the invention. In the past, innovation was seen as a process or sequence of activities, and environmental factors such as company culture and human resources were less important. Due to this fact, collaboration between industry and universities has to be straightened to achieve mutual benefit and enabling better solutions for society.

Through the analysis of data based on the number of publications, patents/patent applications and created spin-off companies, we were able to show that the research activities of Slovenian researchers even compare favourably those of Swiss researchers in terms of quantity. Based on these findings, we surmise that the Slovenian educational system is capable of educating researchers who can follow modern research culture. However, the Slovenian research environment is lacking in research excellence and recognition, as well as in economic relevance and collaboration with industry. These are the key factors that influence the degree of innovation and need improvement with novel approaches.

4 CONCLUSIONS AND POLICY IMPLICATIONS

Academic entrepreneurship, the creation of university companies (startup/spin-off/spin-out) and student entrepreneurship are important innovation channels, but they still represent only a small part of the university's contribution to the Slovenian innovation society. One may ask why the large numbers of academic papers, applied patents and spin-offs created do not have a greater impact on innovation despite the fact that universities also carry out applied and strategic research. Most likely, such research is insufficient at Slovenian universities regarding the quality (low level of co-publishing, low level of publishing in the most relevant scientific reviews, relatively low science citation index with impact factors below 5, etc.).

In terms of promoting innovation and improving research collaboration with both the private and public sectors, Slovenian universities should strive to establish entrepreneurial visions through supporting the transformation of the results based on basic research into applied research (Stanovnik Uršič, 2019). Here, it would be appropriate to emphasize the necessity for two-way flow of experts from universities to the industry and vice versa. In addition, the research policy should strive to change the structure of publicly funded research in favour of targeted applied research. It should provide institutions with stable funding for applied research and regulate the allocation of funds based on the success of projects. Frameworks for monitoring knowledge transfer activities should be created to enable universities to measure their own impact on innovation.

In our analysis, based on available data we concluded that researchers at Slovenian public universities can compete with their Swiss colleagues in terms of research activity. We were able to show that the number of applied patents and created spin-off companies is comparable or even slightly higher, calculated on the number of researchers. Based on these research results, on practical experience in Basel university and on Strengthening Slovenian eco-innovation system (2021), some suggestions are made, which could contribute to improve research excellence and innovation capability in the Slovenian academic environment.

These are also topics which demand further and deeper empirical research of Slovenian high educational and innovation system.

- Entrepreneurship and innovation education should be deeply integrated into education already in secondary schools, and at the latest in the higher education system;
- Universities are not sufficiently focused and do not achieve a critical mass of entrepreneurial knowledge through offered education. Entrepreneurial education is important in all disciplines and not only in business schools. This is important especially at the technical and scientific departments, where many innovative ideas originate.
- Technical faculties should more connect/ collaborate with business faculties and make a joint effort to promote the exchange of knowledge and ideas among students. The transformation of technological inventions based on university research has market potential, so it is important that more independent spin-off companies are established. It is recommended that universities serve society and offer knowledge that is in demand.
- In addition, universities should experiment more with new initiatives, where different innovation activities would be connected/involved in a more coherent structure both within the university ecosystem and especially outside the academic world.
- Universities should explicitly define the goals of innovation, knowledge transfers and entrepreneurship. In setting these goals, faculty-level strategies should be aligned with institutional strategic and national priorities (Slovenian Recovery and Resilience plan 2021-2027).
- Employment and career opportunities should be created through the promotion of innovation and entrepreneurial activity. Entrepreneurial teaching and learning, which includes teaching innovation methods and finding ways to promote creative thinking at all levels of higher education, should be more encouraged. Additional courses that promote entrepreneurship, pedagogical methods, self-initiative, creativity, problem-solving skills, experiential learning and practice should be included in curriculum at all faculties.
- More resources should be created to support teachers and mentors involved in entrepreneurship teaching and learning activities, including support from industry experts.

List of abbreviations:

CERN	European Organization for Nuclear Research
COBISS	Co-operative Online Bibliographic System&Services
EMPA	Swiss Federal Laboratories for Materials Science and Technology
EPFL	Swiss Federal Institute of Technology Lausanne
ETH	Swiss Federal Institute of Technology Zurich
EU	European Union
GDP	Gros Domestic Product
GII	Global Innovation Index
IJS	Inštitut Jožef Stefan
IP	Intellectual Property
R&D	research and development
Ube	University of Bern
UFR	University of Fribourg
UGe	University of Geneva
ULJ	Univerza v Ljubljani
Ulus	University of Lausanne
UM	Univerza v Mariboru
Unibas	University of Basel
UP	Univerza na Primorskem
USA	United States of America
USG	University of St.Gallen
UZu	University of Zurich

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