RISIS

RESEARCH INFRASTRUCTURE FOR SCIENCE AND INNOVATION POLICY STUDIES

KEY ENABLING TECHNOLOGIES IN EUROPE: INSIGHTS FROM PATENTS AND TRADEMARKS

RISIS Policy Brief Series

Issue #12 | September 2022

CONTENTS

Key Enabling Technologies - Industrial Biotechnology, Nanotechnology, Micro and Nano-Electronics, Photonics, Advanced Materials, Advanced Manufacturing Technologies - have been put high on the European policy agenda since the late 2000s. They are seen as highly relevant preconditions/inputs to secure the competitiveness in many sectors and areas as they are known to be key enablers for subsequent technological developments in other fields.

This policy brief intends to shed a light on the diffusion of **Key Enabling Technologies** as such as well as in different areas of application. We compare trends of the **EU-27 countries** with relevant international competitor/partner countries, based on patent applications - from the PATSTAT database - and trademark filings from the ISI-Trademark Data Collection (ISI-TM), which offers a unique data source for the analysis of the diffusion of technologies.

1. INTRODUCTION

The technological competitiveness of nations is broadly distributed across different technology areas, defining the specialisation portfolio of a country. However, technological fields and technological markets change. In particular, the **inputs to high-tech sectors** and technological areas evolve over time.

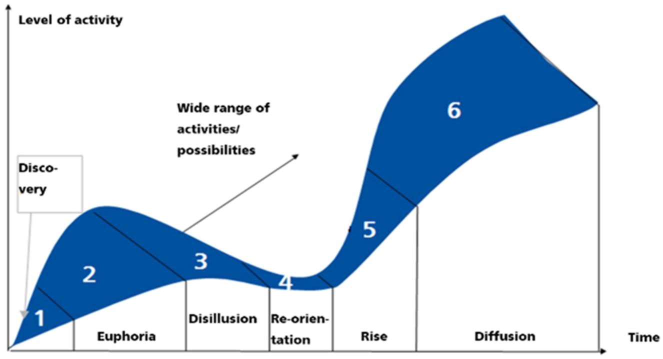
Key Enabling Technologies (KETs) are one of the core inputs to future competitiveness also in current and future sectors of European technological advantage. A demarcation of six KETs - (1) Industrial Biotechnology, (2) Nanotechnology, (3) Micro and Nano-Electronics, (4) Photonics, (5) Advanced Materials, (6) Advanced Manufacturing Technologies - was first put forward in mid 2000s - and became a focal point of policy action in Europe ever since.[1] The European Commission ascribes a broad impact to them when they write: "These KETs drive innovation throughout the economy and cut across industries with a trend towards full convergence and integration."[2]

A central characteristic of KETs is that they play a role in many sectors and for numerous applications and products (Izsak et al. 2021).

The diffusion of innovations has been discussed in the scientific literature already in the late 1950s when Everett Rogers (2003 [1962]) started his seminal work on diffusion factors. This idea has been taken up by many researchers well as in further diffusions models, e.g. the Gartner Hype Cycle[3] model or the technological-readiness levels (TRL) by the NASA , which have recently been implemented by the JRC to describe the TRL of innovations emerging out of projects of FP7 and H2020 in their InnoRadar.[4]

The process of the evolution and emergence of technologies has been analyzed by Utterback and Abernathy in the 1970s (Utterback and Abernathy1975), who stated that **competing technological solutions** coexist until one of them becomes the "dominant design", which then matures and diffuses, which often leads to two overlapping diffusion curves where a first curve already follows a decreasing trend.

Figure 1. A model of technological development



Source: Dreher et al. (2005); Meyer-Krahmer und Dreher (2004); Friet-

Meyer-Krahmer and Dreher (2004) took up the idea of overlapping diffusion curves and of double hypes, when they suggested a general model for the generation of technologies. Their model contains six ideal-typical phases of the **emergence of technologies** and was immediately meant for empirical implementation. In a number of publications this model had been empirically tested and proved based on a number of different technologies (e.g. Dreher et al. 2005; Schmoch 2007). This model - first of all - addresses the generation of technologies, while the market adoption and diffusion was neither part of the model by Meyer-Krahmer and Dreher (2004) nor by the empirical implementation by Schmoch (2008).

In this paper we intend to close this particular gap by resorting to trademarks as market diffusion indicator of technologies that supplements the technological diffusion perspective addressed by scientific publications and patent applications. We find, indeed, that the European Paradox - this refers to a supposed commercialisation deficit in relation to scientific and technological strengths - is not evident for Key Enabling Technologies. European companies and research organisations are able to build and maintain a leading position in this area in the European market, reflected by a comparative advantage in trademark filings.

2. METHODOLOGY AND DATA

The data we use for the study comes from various sources. Trademark data for EUIPO filings are taken from the ISI-Trademark Data Collection (ISI-TM) that has been developed within the RISIS2 project. The dataset is based on original data that has been provided by the EUIPO. It contains trademark information back to the year 1996. Trademarks can be seen as a complementary and relati vely "close to the market" indicator for new products and innovation activities, especially in the service sector, and enables us to indicate innovation diffusion within different technology fields.

The patent data for the study are extracted from the "EPO Worldwide Patent Statistical Database" (PATSTAT). PATSTAT covers information about published patents from 83 patent authorities worldwide, dating back to the late 19th century.

For the analyses of scientific publications, Elseviers' Scopus database is applied, which provides information on articles published in about 23,000 journals worldwide.[6] Based on this database, a detailed analysis of scientific publications and citations is possible for any country in the world. Scopus mainly covers journal articles.

In order to classify the KETs within the three databases, we apply different methods. For patents, we resort to the latest definition published by the KETs Observatory, which has been continued within the Advanced Technologies for Industries (ATI) definition of KETs patents (European Commission 2021). For publications, we generated a KETs definition based on ASJC classes, i.e. the journal classification from Scopus, and keywords. For trademarks, we resorted to an in-depth classification of trademarks described in Neuhäusler et al. (2021), since the NICE classes are too broad for such an assignment.

3. FINDINGS

In this section, we will discuss the findings of our analyses regarding the scientific and technological developments within the KETs over the past 20 years.

Worldwide trends of publications, patents, and trademarks in KETs

The absolute trends within KETs across our selected innovation indicators show that advanced materials is the largest KET across all indicators, followed by industrial biotechnology. Micro- and nanoelectronics as well as nanotechnologies are comparably small fields, whereas photonics lies somewhere in the middle.

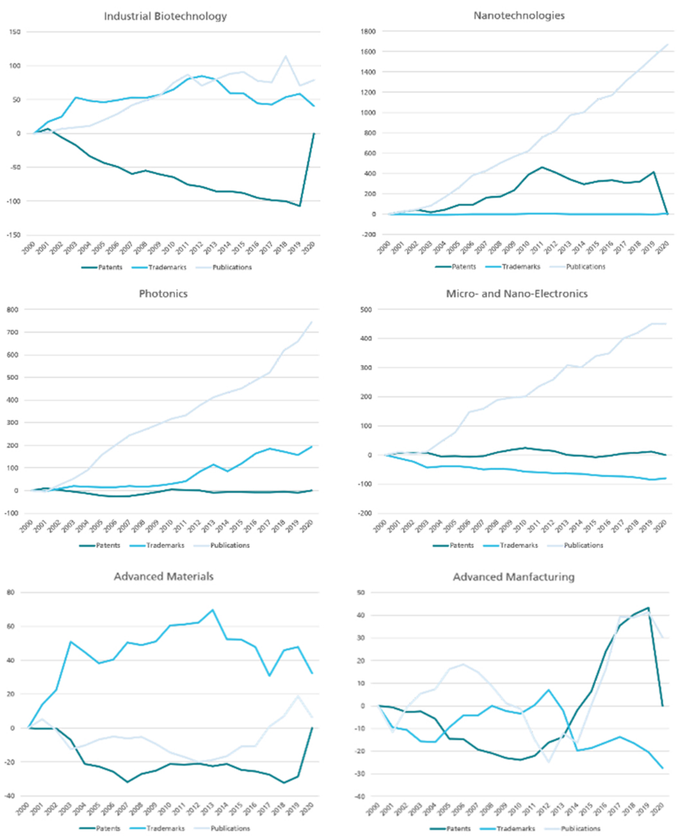
What we also can observe is the rise in scientific publications over the years, which can be found for all KETs. A similar statement can be made for the trademarks. Patents, however, partly tell a different story. In industrial biotechnology, for instance, there has been a downswing in worldwide transnational patent filigns over the observation period, although the figures have slightly increased in the last few years. For nanotechnologies, where all in all only a small amount of transnational patents are filed, a peak can be observed in 2011, followed by a downturn until 2018. However, also here the figures start to rise in the last few years. These two trends might point towards the models of technology development and diffusion following a double-boom cycle that have been discussed in the introduction. At this rather broad, macro-oriented level, however, it is hard to make statements about phases in the technology cycle or technology readiness, which is why we look at the more disagreggated trends in the section 3.3.

What is still of major interest at this point, is to get an impression of growth rates within the KETs. The underlying question is not only whether the fields have grown over the observation period, but if they have grown below or above average (Figure 2).

For this purpose, we calculated the annual growth rates across all three indicators, with the value of the year 2000 set to 100. We then related the growth in the single KETs to the worldwide growth of patent filings. Values above 0 thus show an above average growth, whereas values below 0 resemble a growth rate below the worldwide average. This analysis leads to a more differentiated picture across the KETs. Within **industrial**

biotechnology, we find above average growth rates in scientific publications as well as trademarks, which speaks for a rather large amount of scientific knowledge that is produced but also products that come to the market, at least in Europe. For patents, i.e. the technological side of the medal, the opposite is true.

Figure 2. Growth rates – adjusted to world growth - within KETs, worldwide



Source: Fraunhofer ISI analysis, based on EPO – PATSTAT, EUIPO, Elsevier – Scopus.

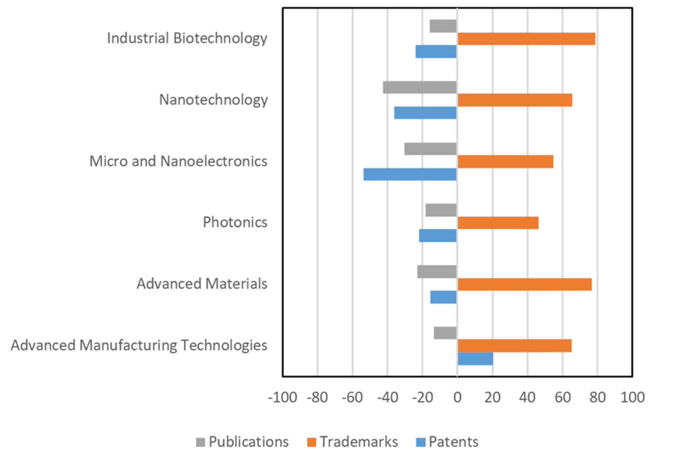
In **nanotechnologies,** we can observe a steep growth in scientific publications, which indicates that this technology is still in the early phase of its development. This is backed by the patent as well as by the trademark indicator. Technological diffusion still happens only at an average rate within nanontechnologies. Very similar trends as for nanotechnologies can be found for **micro- and nanoelectronics,** only that patent and trademark growth happens at an even slower rate. The growth in scientific publications in **photonics** is comparably large, while patent growth has only been at an average level across the last 20 years. The developements in **advanced materials** differ strongly from the other fields. Here, we see a rather mature field with below average patent and publication figures over the years. Yet, trademarks have grown quite extensively within the observation period.

With **Advanced Manufacturing Technologies** (AMT) we finally have one more field with rather diverse trends. AMT thus once again seems to be a field where several technological developments overlap. We can observe growing trends on all indicators until 2012, but a decline afterwards. This suggests a boom of first technological solutions that then entered the phase of "disillusionment". The models would - in an idealtypical case - expect a second boom to emerge in the coming years. The trend of publication data might imply that the next technological paradigm in AMT is about to take off.

Europe's competitiveness in KETs

In terms of the innovation chain, we presented three indicators representing different stages of this chain. Publications stand for the abilities to generate basic and applied scientific knowledge that then feeds into the technology generation (patents) and the trademarks indicate the diffusion of products on markets. In essence, based on the three indicators we can analyse the competiti ness of the EU countries in all three stages of this innovation chain. We use the specialisation index - a measure to assess, if a field has a higher or lower weight in the profile of a country/region than in the world - to examine the standing of the EU-27 member countries in each part of this innovation chain.

Figure 3. Specialisation profile of EU-27 countries in publications, patents and trademarks, 2018-2020*



**** Patent data covers the period 2017-2019, due to the publication period of patent data.**
Source: Fraunhofer ISI analysis, based on EPO – PATSTAT, EUIPO, Elsevier – Scopus.

Figure 3 shows the indices for the six KETs in the period 2018-2020. Since the beginning of the new century (data not shown), the standing of the EU in all of the KETs has considerably improved. However, excpet for AMT, the scientific (publications) and technological (patents) outputs in KETs are below the world average. In other words, other countries put an even stronger emphasis on thes fields in terms of science and technology than Europe does. The trademark data, on the other hand, indicate a strong focus on KETs in all six areas. As the basis for this analysis are EUIPO trademarks that address the European market, EU-27 countries might have a home advanatge. However, as the index is independent of size effects, both of countries and fields, the home advantage ıs such should be compensated.

These findings suggest that the European policies for KETs obviously took effect in terms of the scientific and technological profile. It also had a positive effect on the scientific and technological competitiveness of Europe in all six KETs fields. Even more interesting is, however, to note that the position of European companies on the European market for KETs is outstanding. There seems to be a strong focus on the commercialisation of the technological competences within Europe.

Technological development and diffusion of selected technologies

Europe's increasing position in science, technology, but also the outstanding market engagement were shown above. The evolution of several technologies, however, is not visible at the level of technological areas (like that of individual KETs), but become only apparent at the level of individual technologies. For example, fuel cells are not a technology in a strict sense as a number of different technological solutions qualify as fuel cell technologies, like PEM (polymer electrolyte membrane), SOFC (solid oxide fuel cells), MOFC (molten oxide fuel cells), and numbers of others. While some of these (potential) technological solutions might proof as being worth to be continued and lead to satisfying results in certain contexts or application scenarios, others might not. In consequence, some technological pathways will be kept and others will be abandoned.

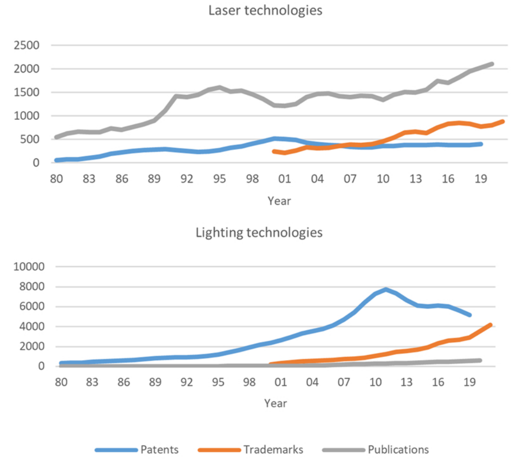
In the following, we examine a few selected technologies within KETs to address two major questions. The first is: Do technological solutions within KETs follow the idealtypical double-boom trend and become mature? Second, when does the diffusion in technology markets occur in relation to the scientific and technological evolution?

We selected five distinct technologies within the KETs, which we were able to - more or less - demarcate for the analysis of all three indicators, namely publications, patents, and trademarks. The trends for two of these - laser technologies and lighting - are depicted in Figure 4.

While the idealtypical trends are not obvious in all five cases, a first increase, a subsequent retardation which is called "disillusionment" in several of the above presented models, and finally a second increase period can be found in most cases. The second boom period is highly associated with a steep increase also in market penetration, reflected in trademark filings.

As technologies and their propensity to patent as well as their scientific versus application orientation vary, a perfect or general relation of publication, patent, and trademark application numbers cannot be expected. We therefore correlate the three time series for each of the five technologies and thereby estimate the delay of effects (time-lag). It is interesting to note that for almost all of the KETs we find a time-lag of zero or of just one year (except for biotechnology with a time lag of about six years). This might at least partly be explainable by clinical test phases and regulatory impacts in this area.

Figure 4. Publications, patents and trademarks in laser technologies and (modern) lighting technologies (energy saving light-bulbs and LED light-bulbs)



Source: Fraunhofer ISI analysis, based on EPO – PATSTAT, EUIPO, Elsevier – Scopus.

4. IMPLICATIONS

The scientific and technological competitiveness in Key Enabling Technologies is in the focus of European policy making, both at the EU as well as the national level in many member states for more than a decade. KETs are supposed to be essential inputs to technologies and technological developments in other innovation-driven areas. The outcomes of these policy efforts can be seen in the number of journal publications as well as in the number of patent filings. However, international competitors in the USA, Japan, and more recently especially in China are not only pushing in the European market, but compete with Europe worldwide. The diffusion of the technical solutions in the area of KETs accelerated in the first and second decade of the 2000s. Europe was able to achieve a strengthening of its capabilities, both in upstream (science and technology) as well as donwstream (market activities) more or less in parallel. Europe takes a strong position, at least in the European market, for which we were able to provide empirical evidence.

Further implications for future policy making are:

- Application orientation in KETs and other crucial technological fields is a mandatory prerequiste for bridging the gap between science/technology and the market. The funding programs should take that into account.
- Diffusion as a policy aim should be prioritised from the beginning and become a standard part/request in any of the funding programs for applied technological research - among them KETs.
- Demand-side policies (e.g public procurement, innovation friendly regulation, education and qualification in the area of new technological applications, ...) are able to support diffusion and thereby competitiveness as well as security of supply.
- KETs need to be regularly checked for continuing to be key enablers. Given that the key enabling character persits, the technological sovereignity and the supply chains are to be secured.

Notes

[1]Only recently the EC adapted its definition of KETs by merging some fields and adding a few others. The new categories are: advanced manufacturing, advanced materials, life-science technologies, micro-/nano-electronics, artificial intelligence, and security and connectivity. However, we stick with the previous list as these definitions are already well-established and data is available for these, whereas the new list of KETs still requires broad diffusion.

[2]https://research-and-innovation.ec.europa.eu/research-area/industry/key-enabling-technologies_en

[3]https://www.gartner.com/en/research/methodologies/gartner-hype-cycle

[4]https://www.nasa.gov/directorates/heo/scan/engineering/technology/technology_readiness_level;https://ntrs.nasa.gov/citations/19890030268

[5]https://www.innoradar.eu/methodology

[6]www.elsevier.com/__data/assets/pdf_file/0007/69451/Scopus_ContentCoverage_Guide_WEB.pdf

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To develop a deeper understanding of knowledge dynamics and policy relevant evidence, RISIS goes beyond established quantitative indicators, developing positioning indicators, in order to reduce asymmetries in actors producing new knowledge, in places where knowledge is generated, and in themes addressed.

RISIS community is dealing with sensitive issues as social innovation, non-technological innovation, the role of PhDs in society, and portfolios of public funding instruments, studying both universities and firms.

This project is funded by the European Union under Horizon2020 Research and Innovation Programme Grant Agreement n°824091

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Peter Neuhäusler | Fraunhofer ISI
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