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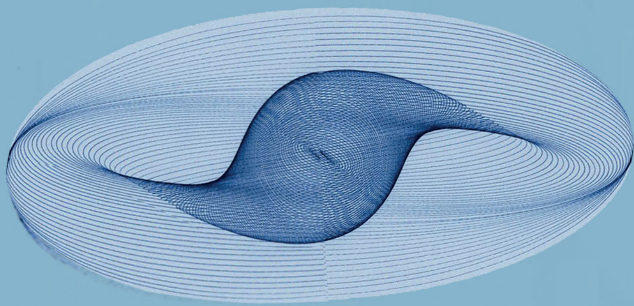

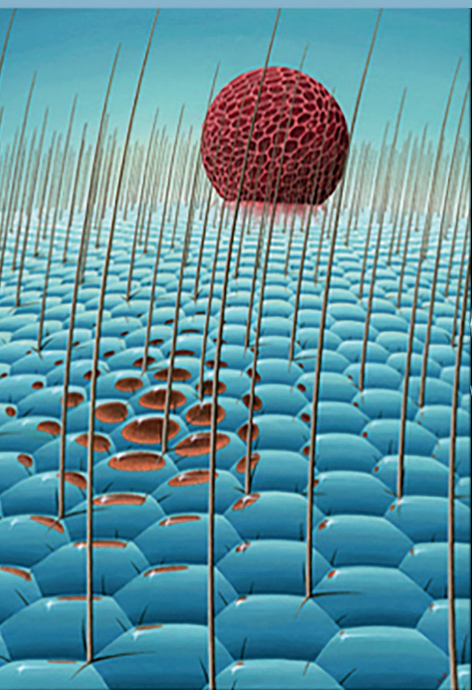

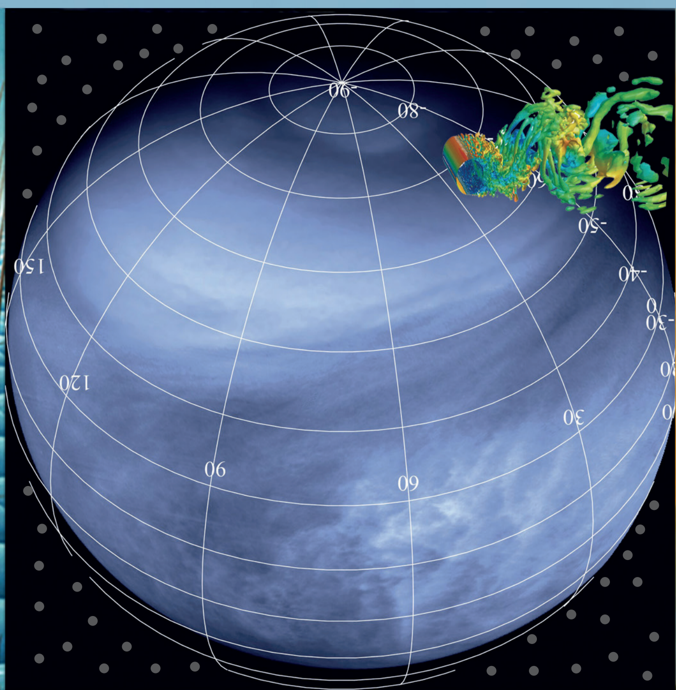

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National Research University
Higher School of Economics

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Address:
National Research University Higher School of Economics
20, Myasnitskaya str., Moscow, 101000, Russia
Tel: +7 (495) 621-40-38
E-mail: foresight-journal@hse.ru

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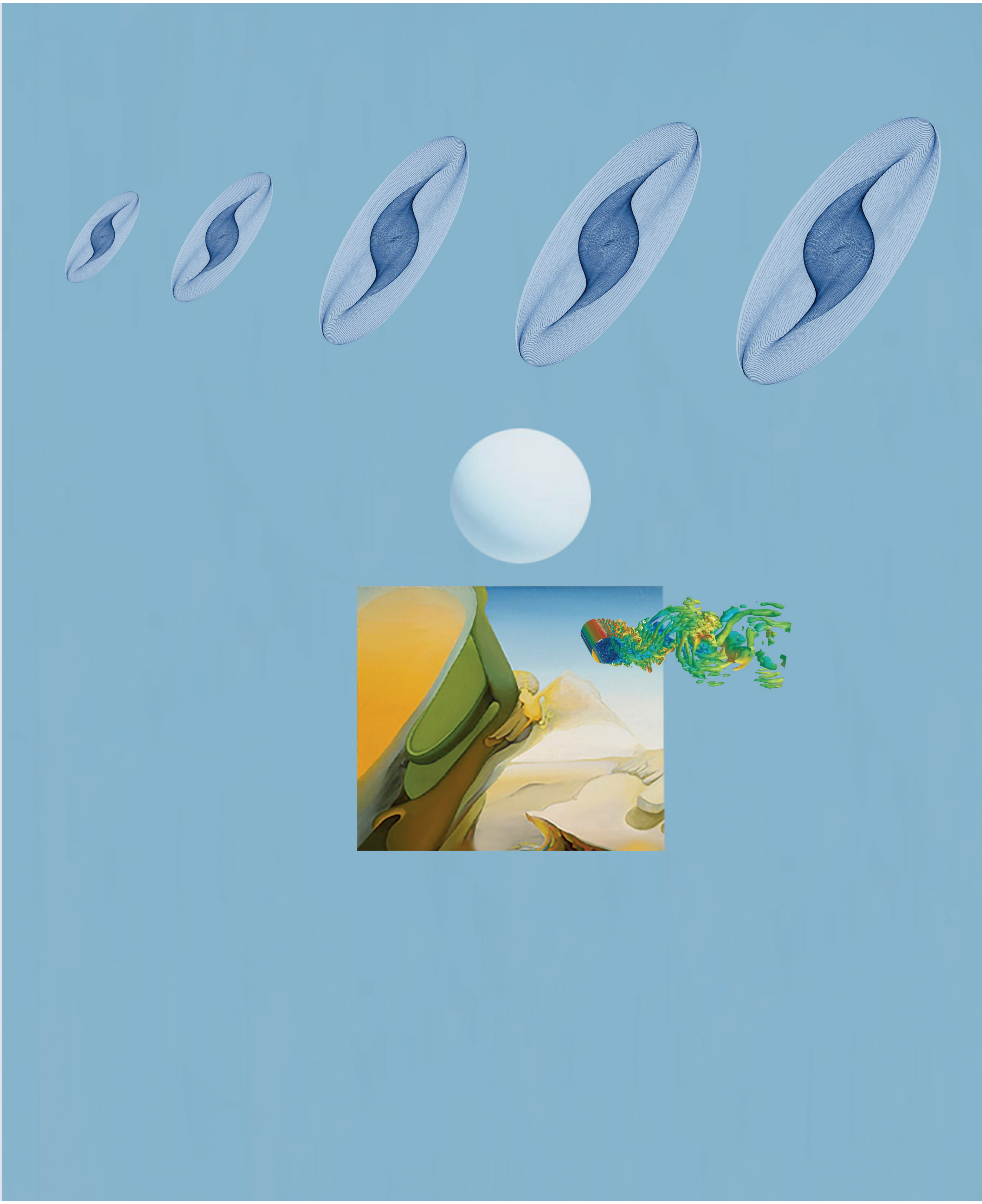

Future of Bioprinted Tissues and Organs: A Two-Wave Global Survey

Fabio Batista Mota
Researcher [a], fabio.mota@fiocruz.br

Luiza Amara Maciel Braga
Associate Researcher [a], PhD Student [b], luiza.braga@fiocruz.br

Bernardo Pereira Cabral
Associate Researcher [a], Professor [c], bernardo.cabral@fiocruz.br

Carlos Gilbert Conte Filho
Associate Researcher [a], Professor [d], carlos.conte@fiocruz.br

[a] Oswaldo Cruz Foundation, Brasil Avenue 4036, 21040-361, Rio de Janeiro – RJ, Brazil
[b] Fluminense Federal University, Rua Prof. Marcos Waldemar de Freitas Reis, 24210-200, Rio de Janeiro – RJ, Brazil
[c] Federal University of Bahia, Treze de Maio Square 6, 40.060-300, Salvador – BA, Brazil
[d] Federal University of Santa Maria, Independencia Avenue 3751, 983000-000, Santa Maria – RS, Brazil

Abstract

Technologies of 3D- and 4D-bioprinting make it possible to restore or replace tissues and organs, solving the problem of the lack of donor resources and reducing the risks of implant rejection. This article presents the results of a two-stage global survey of specialists in tissue engineering on the prospects of bioprinting in preclinical studies and clinical practice. A picture of possible tracks and horizons upon which the implementation of the considered solutions is possible is presented. According to the results of the survey, in the next two decades it will be possible to recreate tissues and organs suitable for implantation and drug testing. There will be a market for bioprinted products, the problem of organ shortages and adverse reactions to drugs will be solved. These changes may significantly affect not only the practice of biomedical research, drug testing, and medicine, but also the healthcare sector in general, which implies the need for a preventive review of current policies. A practical and accessible tool for identifying and interviewing a large number of experts around the world is proposed, which may be useful for new Foresight studies.

Keywords: future medicine; innovation ecosystem; 3D/4D-bioprinting; bioprinted organs; toxicity testing; organ implantation; tissue engineering; survey; expert opinion.

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Introduction

Tissue and organs engineering is highly relevant to medicine due to huge impact on quality and longevity of life. There are new technologies currently being developed in research labs, which hold the potential to restore or replace tissues and organs in the future. These technologies include bioprinting of tissues and organs, recellularization[1] strategies, cellular repair or regeneration, and xenotransplantation (Hunsberger et al., 2016). Overall, three-dimensional (3D) printing technologies are usually seen as forming a very complex innovation ecosystem (Beltagui et al., 2020).

In this study, we focus on 3D and four-dimensional (4D) bioprinting technologies, and more specifically the bioprinting of tissues and organs. Bioprinting is a process for printing biological and functional systems (Thayer et al., 2020) that makes use of cells, biomaterials, biomaterial scaffolds, growth and biological factors (Ahn et al., 2016; Mao et al., 2020). The term three-dimensional refers to the printing of three-dimensional objects from digital models, and four-dimensional to the use of stimuli-responsive materials (Ashammakhi et al., 2018; Yang et al., 2019; Yu et al., 2020). The 4D bioprinting method uses the same bioprinter as 3D bioprinting. The difference is the use of stimulus-responsive materials, as inks, also called smart materials (Yang et al., 2020). When receiving a given external stimulus after they are bioprinted, 4D bioprinted constructs can transform, grow or shrink (Yang et al., 2019; Yang et al., 2020). Thus, in 4D bioprinting stimuli-responsive materials allow the bioprinted tissues and organs to change over time according to given environmental stimuli (Mao et al., 2020).

The global 3D bioprinting market size was valued at USD 1.4 billion in 2020 and is expected to reach USD 4.4 billion by 2028. Possible drivers of this increase are the lack of organ donors associated with an increasingly aging population with chronic diseases worldwide (Grand View Research, 2021). With such a large market expected for the coming years, in addition to the emergence of 3D bioprinting startups, 3D printing companies are expanding their business to offer bioprinters and hardware to take advantage of the growth opportunities offered by this expanding market (Combellack et al., 2018). In this emerging field, most of the companies were founded in the 21st century and the majority have 10 or fewer employees (Bicudo et al., 2021). Some relevant companies in this market include the Americans Aspect, Aether, SE3D, Organovo, Tevido, BIOLIFE 4D, Seraph Robotics, BioRobots, ASLS, and nScrypt; the Europeans Ourobotics, Poietis, 3Dynamic, EnvisionTEC, regenHU, REGEMAT 3D, GeSiM, CELLINK, and 3D Bio; and the Asians Sichuan Revotek, Regenovo Biotech, ROKIT, Cyfuse, Pensees and Bio3D Tech (Choudhury et al., 2018). Recent patent mapping has shown that China's Sichuan Revotek and US company Organovo are two of the leading companies with the most patents related to bioprinting (Mota et al., 2020).

Today, this is an unsolved problem that largely relies on health policies aimed at increasing the number of registered donors (Shanmugarajah et al., 2014). Bioprinting technologies offer great promise to provide fully-functional tissue and organs for implantation in humans (Wang et al., 2020b; Yu et al., 2020), which could lead to the elimination of organ shortage in the future (Unagolla, Jayasuriya, 2020; Bea, 2020). Also, bioprinting technologies are expected to provide human-based methods for research and drug toxicity testing (Rosania, 2013; Gardin et al., 2020; Mota et al., 2020), which might lead to the elimination of adverse drug reactions (ADRs) in humans (Haris et al., 2020). As known, serious ADRs can lead to deaths and morbidity, and drug withdrawals. In the United States alone, serious ADRs affect about 2 million patients every year, resulting in 100,000 deaths (Giacomini et al., 2007; Niu et al., 2015). The occurrence of ADRs would be related to the use of animals in preclinical research, considered not to be good predictors of toxicity in humans (Giacomini et al., 2007; Niu et al., 2015). In the coming decades, it is conceivable that human-based methods can replace the use of animals in research and preclinical research (Bandyopadhyay et al., 2018).

So far, a variety of tissues (skin, bone, cartilage, neuronal tissue, etc.) have been generated using 3D/4D bioprinting (Duan, 2017; Heinrich et al., 2019; Lukin et al., 2019). Some examples of successful bioprinted tissues implanted in animals are bones, cartilage, skin, and vascular grafts (Singh et al., 2020; Wang et al., 2020b). An example of a human application was the bioprinting of a tracheal splint, which was implanted in a child with tracheobronchomalacia (Yang et al., 2019). However, the use of bioprinted tissues and organs either in preclinical studies or in human implants is still very limited (Vijayavenkataraman et al., 2018; Murphy et al., 2020). Before this can happen, important challenges such as the building of vascularized tissues and organs must be addressed (Gao, Cui, 2016; Murphy et al., 2020; Zhu et al., 2021). Vascularization is required to maintain bioprinted constructs alive for a long time (Vries et al., 2015). Bioprinting vascularization networks require the improvement of bioprinters and bioinks (Dias et al., 2020; Heinrich et al., 2019). While bioprinters still lack optimal resolution and speed, high-performance bioinks still need to be enhanced with the ability to support cell proliferation, cell differentiation, and tissue/organ production (Albritton and Miller, 2017; Heinrich et al., 2019; Huang et al., 2017; Mori et al., 2018; Park et al., 2016).

One can say, then, that the future of 3D/4D bioprinting as a way to provide human tissues and organs for

[1] Removal of cells from tissue while preserving the extracellular matrix and three-dimensional structure of the organ.

research, toxicity testing, and implantation in humans is still uncertain. As far as we know, a few studies have tried to foresee the future of 3D/4D bioprinting (Mir, Nakamura, 2017; Vijayavenkataraman et al., 2018; Silva, 2019; Mota et al., 2020; Unagolla, Jayasuriya, 2020). Yet, none of them offer a long-term perspective, based on researchers' opinions, on future 3D/4D bioprinting developments and their expected impacts on biomedical research, drug testing, medicine. Our study addresses this gap by assessing the opinions of over 1,400 researchers from around the world in the field of tissue engineering[2] who are authors of recent scientific publications related to tissue engineering indexed in the Web of Science Core Collection (WoS). The respondents' opinions were assessed through a two-wave global web-based survey with a two-year interval (2018 and 2020). The second wave sought to assess if there were changes in expectations regarding the future of tissue engineering technologies that involve the fabrication of functional tissues for regenerative medicine and drug testing (Richards et al., 2013), and aim to enable the replacement, restoration of lost or diseased tissues and organs (Leberfinger et al., 2019; Yu et al., 2020; Zhu et al., 2021). Being both developers and users, it can be said that the researchers invited to take part in this study are among the most qualified to point out future developments of these technologies and their implications on biomedical research, drug testing, and medicine.

This study is based on Technology Foresight (TF) (Martin, 1995; Martin, Johnston, 1999; Georghiou et al., 2008; Martin, 2010; Miles, 2010), which refers to "the process involved in systematically attempting to look into the longer-term future of science, technology, the economy and society with the aim of identifying the areas of strategic research and the emerging generic technologies likely to yield the greatest economic and social benefits" (Martin, 1995). Overall, TF studies aim to provide strategic information for long-term decision-making and planning in science and technology (Martin, 1995; Martin, Johnston, 1999; Georghiou et al., 2008; Martin, 2010; Miles, 2010; Popper, 2008). Yet, as time goes by, advancements in scientific knowledge and technology developments may lead to changes in expectations of the future. This makes the monitoring of changes in expectations about emerging technologies of great importance for decision making and long-term planning in science and technology, and periodic surveys like the one conducted in this study are a way to address this task.

Technology Foresight and intertemporal comparison of researchers' expectation

Approaches to forecasting technology emergence arose more systematically after the Second World War, mainly because technological progress started to be seen as a result of collective knowledge cumulativeness rather than the result of individual efforts (Miles et al., 2017). This perception led to the creation of new tools to support forecasting technologies, ranging from quantitative analysis developed by the US Department of Defence to qualitative approaches developed at think tanks like the RAND Corporation (Linstone, 2011). At first, these efforts undertaken in the 1940s and 1950s in the United States were put under the broader terms 'forecast' and 'forecasting', and then becoming known as Technological Forecasting. It aimed to provide probabilistic results with a high degree of confidence about the future, giving somewhat of a deterministic view of economic and innovative dynamics. Later, in the late 1980s and early 1990s, another approach would recognize that choices made today shape the future in a non-deterministic way, and are socially and politically affected by the agents involved in the decision-making processes (Martin, Irvine, 1989; Martin, 2010). That approach is what is known today as TF. The TF approach was initially outlined by John Irvine and Ben Martin in an attempt to delineate a field of research for future-oriented studies in science and technology (Irvine, Martin, 1983; Martin, Irvine, 1989). Their works were especially important to distinguish TF from Technological Forecasting and to establish the first as the standard for technology emergency analysis in innovation studies (Martin, 2010; Miles, 2010). Later, other authors continued to explore this differentiation and added that TF also had the potential to influence the direction technology takes and help the desired future to materialize (Miles, 2010) and that its participatory structure ensured the inclusion of agents who can expand potential strategies beyond individual interests (Lall, 2004).

Foreseeing technologies that may be economically or socially relevant in the future is key for governments that aim to enable long-term economic growth and productivity, improve the delivery of public services, enrich the lives of its citizens and inform policy development (Government Office for Science, 2017). This is true for many areas but healthcare is certainly among the ones that benefit the most from innovations. From new devices such as labs-on-a-chip (LOCs), that may lower costs and increase access to diagnostics (Mendes et al., 2019), to 3D/4D bioprinted tissues and organs, that can replace diseased, damaged, or lost human tissues and organs (Jang et al., 2016; Kačarević et al., 2018; Lerman et al., 2018). TF projects often have a form of broad government-funded studies that may require large amounts of money, resources, and personnel. Our method, in turn, is low-cost, requires fewer researchers, produces faster results, and can collect opinions of experts from all over the world. It consists of conducting periodic web-based surveys to re-evaluate previous TF studies and thus identify whether there have been changes in experts' expectations regarding the

[2] Tissue engineering is an interdisciplinary field that combines chemistry, biology, and engineering (Richards et al., 2013).

Box 1. **Search Queries**

(ti=("4D bioprint*" OR "4D bio-print*" OR "four-dimensional bioprint*" OR "four-dimensional bio-print*" OR "4-dimensional bioprint*" OR "4-dimensional bio-print*" OR "four-D bioprint*" OR "four-D bio-print*" OR "4D print*" OR "four-dimensional print*" OR "4-dimensional print*" OR "four-D print*" OR "3D bioprint*" OR "3D bio-print*" OR "three-dimensional bioprint*" OR "three-dimensional bio-print*" OR "3-dimensional bioprint*" OR "3-dimensional bio-print*" OR "three-D bioprint*" OR "three-D bio-print*" OR "3D print*" OR "three-dimensional print*" OR "3-dimensional print*" OR "three-D print*") and ti=(«Tissue Engineer*» OR «tissue culture*» OR «Cell Engineer*» OR «cell culture*» OR «Bioengineer*» OR «Bio-engineer*» OR «organ* culture*» OR «in vitro»)) AND LANGUAGE: (English)

Indexes = SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH, ESCI Horizon = 2013-2018

(ti=("animal* testing alternative*" OR "alternative* to animal* testing" OR "animal* use alternative*" OR "alternative* to animal* use" OR "animal* experiment* alternative*" OR "alternative* to animal* experiment*" OR "animal* research alternative*" OR "alternative* to animal* research" OR "animal* model* alternative*" OR "alternative* to animal* model*" OR "lab* animal* alternative*" OR "alternative* to lab* animal*" OR "reduction refinement and replacement*" OR "3Rs" OR "three-Rs")) AND LANGUAGE: (English)

Indexes = SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH, ESCI Horizon= 2013-2018

Source: authors.

future results of a given technology. TF benefits greatly from a reassessment of experts' estimates after some time, whether to better understand experts' projection mechanisms or to assess if their expectations are confirmed (Brandes, 2009; Kaivo-oja, 2017; Apreda et al., 2019). Thus, considering the high degree of novelty of much of the technologies that are subject to TF exercises, the decision-making in science and technology may greatly benefit from intertemporal comparisons of expert opinions. Periodic surveys not only update the results of previous TF exercises but also assess if there were changes in researchers' expectations.

Materials and Methods

Literature review and questionnaire

The questionnaire was based on a literature review of 3D and 4D bioprinting, tissue engineering, and alternatives to animals in research. The publications were gathered in WoS using the following queries (Box 1).

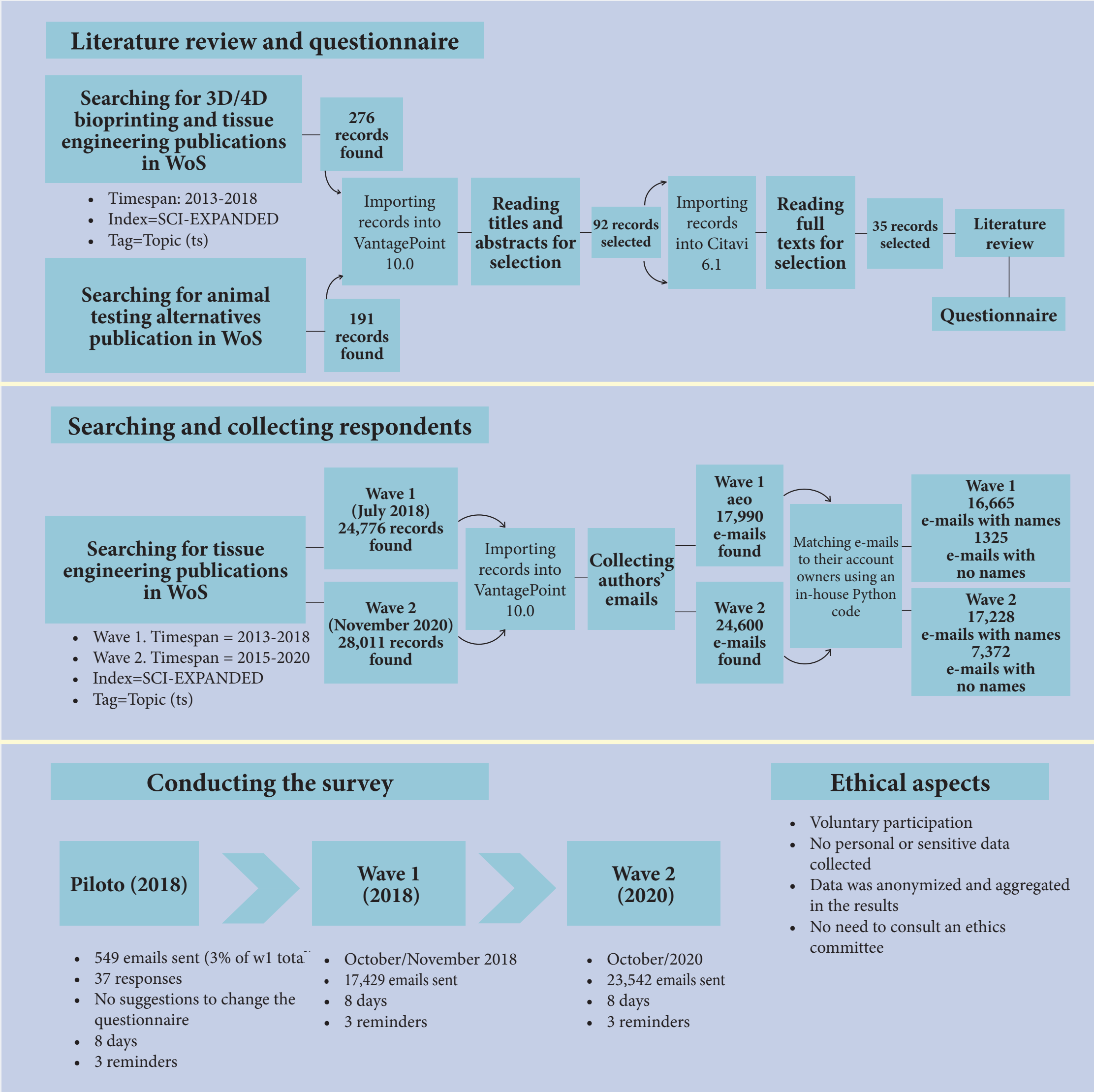
We used the tag Title (ti) to search for the queries' terms only in the publications' titles. Both queries used terms of the Medical Subject Headings[3] and free text words. We used only the Science Citation Index Expanded (SCI-EXPANDED) to collect records of publications (all document types) published in science journals between 2013 and 2018.

The search was done in July 2018 and yielded 276 records of publications (all document types) from the first query and 191 from the second. All the records were imported into the VantagePoint 10.0, where a preliminary selection of the publications was made by reading the titles and abstracts. This procedure reduced the number of documents of interest to 92. These documents were then imported into the reference management software Citavi 6.1, where the final selection was made by reading the full texts. Finally, 35 publications were selected, which formed the basis of the literature review and the questionnaire (Richards et al., 2013; Balls, 2014; Doke and Dhawale, 2015; Fleetwood et al., 2015; Goh et al., 2015; Graham, Prescott, 2015; Mosadegh et al., 2015; Obregon et al., 2015; Stokes, 2015; Zhang, Zhang, 2015; Ahn et al., 2016; Brunello et al., 2016; Colasante et al., 2016; Gao, Cui, 2016; Groeber et al., 2016; Mehrban et al., 2016; Mohanty et al., 2016; Ng et al., 2016; Park et al., 2016; Zhao et al., 2016; Zhu et al., 2016; Albritton, Miller, 2017; Burden et al., 2017b; Cheluvappa et al., 2017; Duan, 2017; Garreta et al., 2017; Huang et al., 2017; O'Connell et al., 2017; Vanderburgh et al., 2017; Almela et al., 2018; Faramarzi et al., 2018; Löwa et al., 2018; Mori et al., 2018; Stratton et al., 2018; Tarassoli et al., 2018).

The questionnaire asked the respondents to consider 2018-2038 (W1) and 2020-2038 (W2) as a future time frame. It was structured into three parts. The first part was designed to ascertain the respondents' level of knowledge of 3D and 4D bioprinting applications in the field of tissue engineering, ranging from no knowledge to good knowledge. Respondents with no knowledge of the survey's subject were disqualified from the survey and did not answer the questionnaire. The second part presented five statements about the future. The aim was to obtain the respondents' opinions on the likelihood of 3D and 4D bioprinting leading to: fully functional human tissues and organs for implantation; repair of lesions directly at the wound site; drug testing models for toxicity testing; human disease models for research; and replacement of animals in research and toxicity testing. They were asked to indicate both the likelihood of each statement and when they expect it would come about (before or after 2038). The final part asked respondents to indicate the likelihood of five selected scientific and technological challenges being overcome within the given time

[3] ncbi.nlm.nih.gov/mesh, accessed 02.06.2021.

Figure 1. **Summary of the Method**



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horizon. These challenges covered expected advancements in bioprinters, vascularisation of tissues, and scalability of bioprinted models. The questionnaire was set to be answered within 2-3 minutes to avoid respondent's fatigue, skipped questions, survey dropout. Demographic questions were not asked because the results of this type of survey are not expected to be influenced by the respondents' demographics (Pereira Cabral et al., 2019a, 2019b; Cabral et al., 2021; Mota et al., 2020; Rocha et al., 2020).

Searching and collecting respondents in scientific publications

The respondents of this survey were found in scientific publications related to tissue engineering indexed in WoS between 2013 and 2018 (Wave 1) and 2015-2020 (Wave 2). To do so, we used the following query:

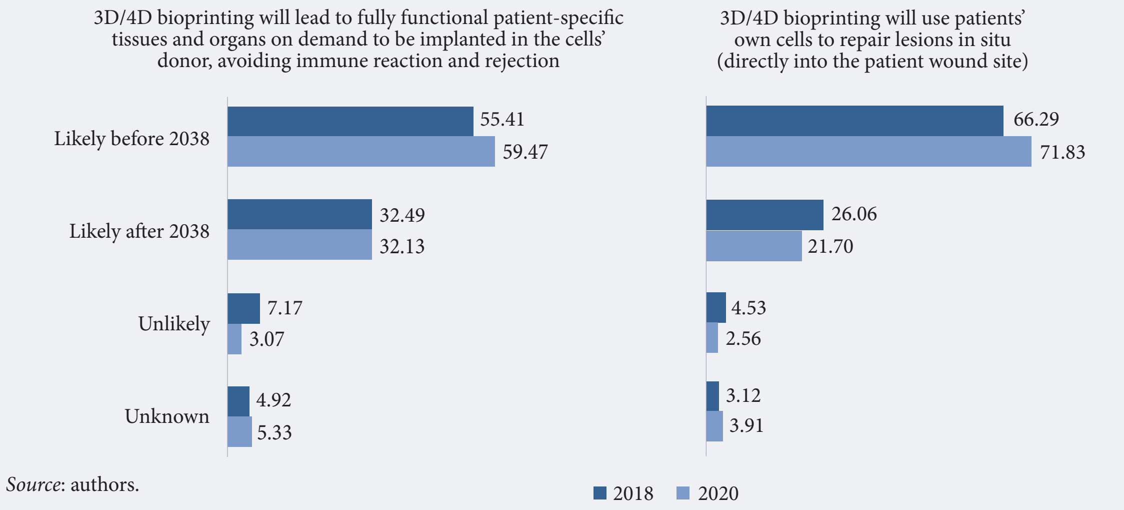
(ts=("tissue engineer*"))

Indexes=SCI-EXPANDED Timespan=2013-2018 (Wave 1) and 2015-2020 (Wave 2)

We used the tag Topic (ts), which searches for descriptors in the publications' titles, abstracts, and keywords, and the term tissue engineering. Since the objective was to find out the expectations of natural scientists, the query was set to retrieve documents indexed in the SCI-EXPANDED. In both waves, the period was set to identify authors who had published their research results recently.

The wave 1 (W1) search was done in July 2018 and retrieved 24,776 records of publications (all document types), and the wave 2 (W2) search in November 2020, retrieving 28,011 records of publications. All the records were imported into the data/text mining software VantagePoint 10.0, where 17,990 (W1) and

Figure 2. **Likelihood of 3D/4D Bioprinting Effects — part 1 (share of responses, %)**



Source: authors.

24,600 (W2) authors' emails were collected. Then, we generated a CSV file to link about 81% of these emails to their account owners using an in-house Python code. Thus, it was possible to forward personalized e-mails with the respondents' names to most of them.

Conducting the Survey and ethical aspects

In W1, we validated the questionnaire through a pilot study with an aleatory sample of 549 respondents (about 3% of the total). As we did not receive any suggestions for changes of the 37 respondents who answered the pilot study, the questionnaire was not modified. The data collected was then included in the statistical analysis of the survey. Since the questionnaire is the same in both waves, there was no need for a pilot study in the 2020 survey. The pilot and the formal study of W1 were conducted between October and November 2018, and the formal study of W2 in October 2020. The questionnaire was available for completion for eight days after the invitation email was sent. All data collected were anonymized in the study results.[4] Figure 1 summarizes the method used.

Statistical Analysis

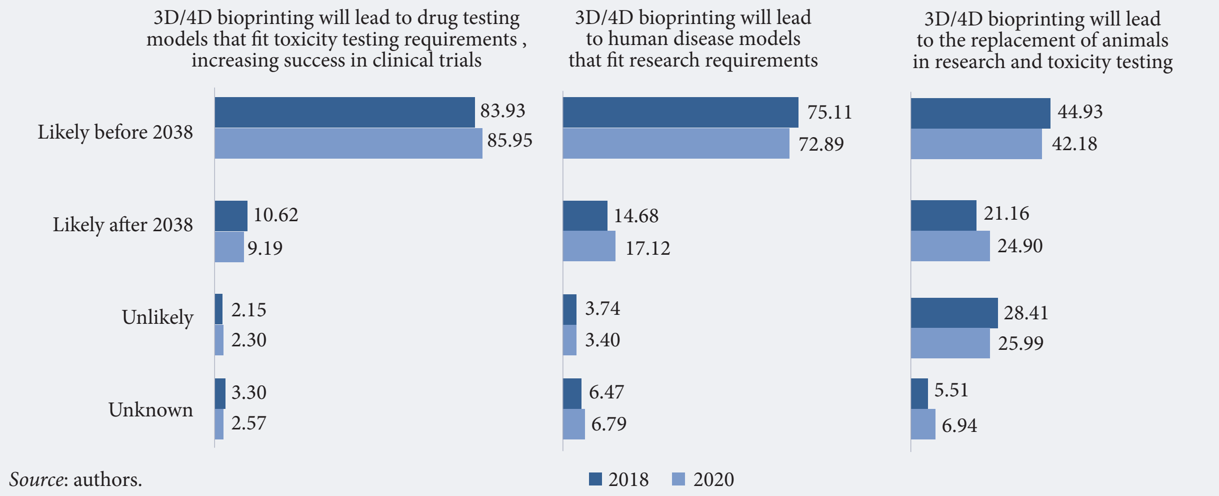
We used the Shapiro-Wilk and the Kolmogorov-Smirnov to test whether the sample follows a normal distribution. The Shapiro-Wilk normality test is usually used due to its good power properties. That is, it is not necessary to know the average and variance of the sample beforehand. In turn, the Kolmogorov-Smirnov is a test of a distribution's adherence to a parameter. It becomes a test of normality when the maximum absolute difference between an expected (normal) function and the empirical distribution of data is observed. Both tests are generally used in empirical studies. The Kolmogorov-Smirnov is more suitable for large samples, while the Shapiro-Wilk test is indicated for small samples (less than 50 observations). As the sample did not follow a normal distribution, we used non-parametric tests with a 95% confidence level.[5]

For the question related to the knowledge level of the respondents, we used the binomial non-parametric test to assess whether the two groups of valid respondents (good knowledge and some knowledge) are statistically homogeneous or whether one is predominant over the other. For all the other questions we used the non-parametric test of Mann-Whitney U to assess whether the level of respondents' knowledge interferes with the predominant median. Additionally, we used the non-parametric tests of Wilcoxon to assess the median of the responses collected. The tests of Mann-Whitney U and Wilcoxon assign value 1 for the lowest rank (position 1), value 2 for the next rank, and so on. This process generates high scores being represented by high posts and low scores being represented by low posts. Lastly, to compare the responses obtained in 2018 with the responses obtained in 2020, the non-

[4] The methods we used to identify respondents from scientific publications, retrieve and link the emails to their account owners, design and manage the web-based survey follow recent future-oriented studies on health-related technologies (Pereira Cabral et al., 2019a, 2019b; Cabral et al., 2021; Mota et al., 2020; Rocha et al., 2020).

[5] Non-parametric tests do not require normally distributed observations, but the distribution of observations in an ordinal scale. Although parametric tests are more robust than non-parametric tests, their use requires normally distributed observations (Hesse et al., 2017), which makes them inadequate for this study.

Figure 3. **Likelihood of 3D/4D Bioprinting Effects — part 2 (share of responses, %)**



Source: authors.

parametric test of marginal homogeneity was applied. The non-parametric test of marginal homogeneity follows a chi-square distribution. It generates a frequency table for each survey and compares them. The data analysis was carried out using the IBM-SPSS Statistics 26. The results of the statistical analysis are available as Supplementary Material.

Results

The results reported here consider all valid responses. To simplify the graphical presentation and the description of the results, we combined the responses of good and some knowledge respondents. The binomial non-parametric test rejects the null hypothesis that there are two groups of respondents (good and some knowledge) each with 50% of the responses. The result shows that, in both waves, respondents who said they have some knowledge are preponderant. Thus, the results obtained in both waves may suffer bias depending on the level of knowledge of the respondents. Significant statistical differences between them will be described in the results when they occur.

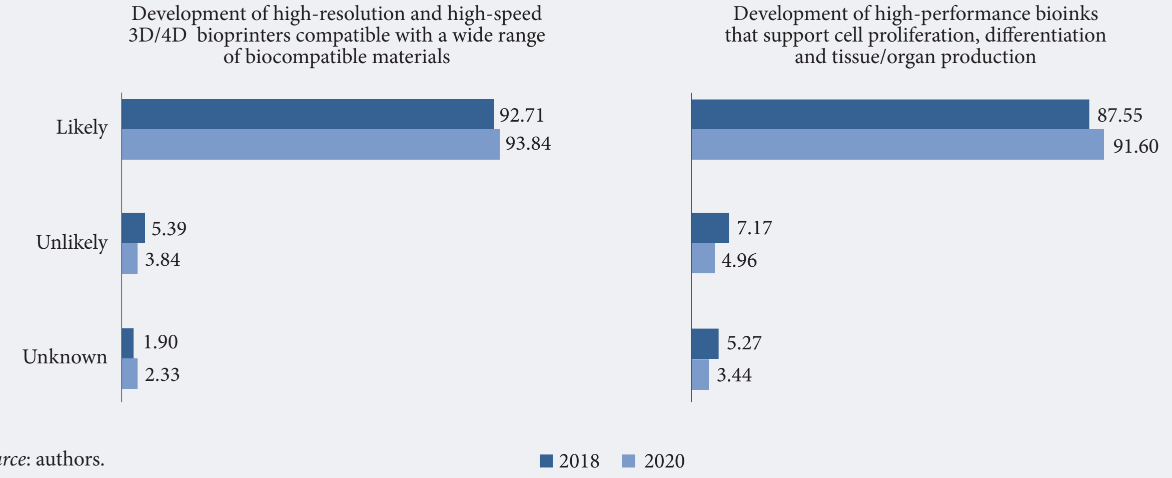
In 2018, 801 researchers accepted to participate in the study, which corresponds to a response rate of 4.3%. Of those, 61 were disqualified from the survey after reporting having no knowledge of 3D and 4D bioprinting applications in the field of tissue engineering. Of the 740 valid responses, 38.4% were from good knowledge and 61.6% from some knowledge respondents. Taking into account only the 673 fully completed questionnaires (90.9% of total valid responses), we obtained a representative sample with a 95% confidence level and a margin of error of 3.7%. As for the 2020 survey, 836 researchers accepted to participate in the study (3.3% response rate), 60 were disqualified for having no knowledge, 40.1% of the 776 valid responses were from good knowledge and 59.9% from some knowledge respondents. We received 708 fully completed questionnaires, which corresponds to 91.2% of the total. Considering these fully completed questionnaires and a 95% confidence interval, the margin of error in the results is 3.6%. Of the 1,516 respondents qualified for the surveys, 110 participated in the two waves. According to the respondents' internet email protocols, researchers from 67 and 66 countries participated in W1 and W2, respectively.[6]

In W1, about 87% of respondents expected that 3D/4D bioprinting will likely lead to fully functional patient-specific tissues and organs on demand to be implanted in the cells' donor, avoiding immune reaction and rejection. In W2 this percentage increased to over 90% (Figure 1). Besides the slight increase in likely responses and the reduction of unlikely responses between 2018 and 2020, the marginal homogeneity test shows that there is no statistical difference between the responses of the two waves. For its part, the Mann-Whitney U test indicated that, in both waves, the level of respondents' knowledge does not interfere with the predominant median. According to the Wilcoxon test, the statistically predominant response, in both waves, is that the 3D/4D bioprinting will likely lead to the mentioned fully functional patient-specific tissues and organs before 2038.

In both waves, according to over 90% of the researchers, 3D/4D bioprinting will use patients' own cells to repair lesions directly into the wound site. Most of them expect it before 2038 (Figure 2). Comparing the experts' opinions between 2018 and 2020, there is a modest increase in the percentage of likely before 2038 and a

[6] In both waves, the highest proportion of respondents were from Europe (38.70% W1; 41.15% W2), followed by Asia (23.82% W1; 25.12% W2), North America (21.52% W1; 15.67% W2), and South America (10.96% W1; 15.19% W2).

Figure 4. **Likelihood of Scientific and Technological Challenges Being Overcome until 2038 — part 1 (share of responses, %)**



Source: authors.

reduction of unlikely. However, the marginal homogeneity test does not show a statistical difference in the responses of the two waves. Besides that, the Mann-Whitney U test indicated that the level of respondents' knowledge also does not interfere with the results.

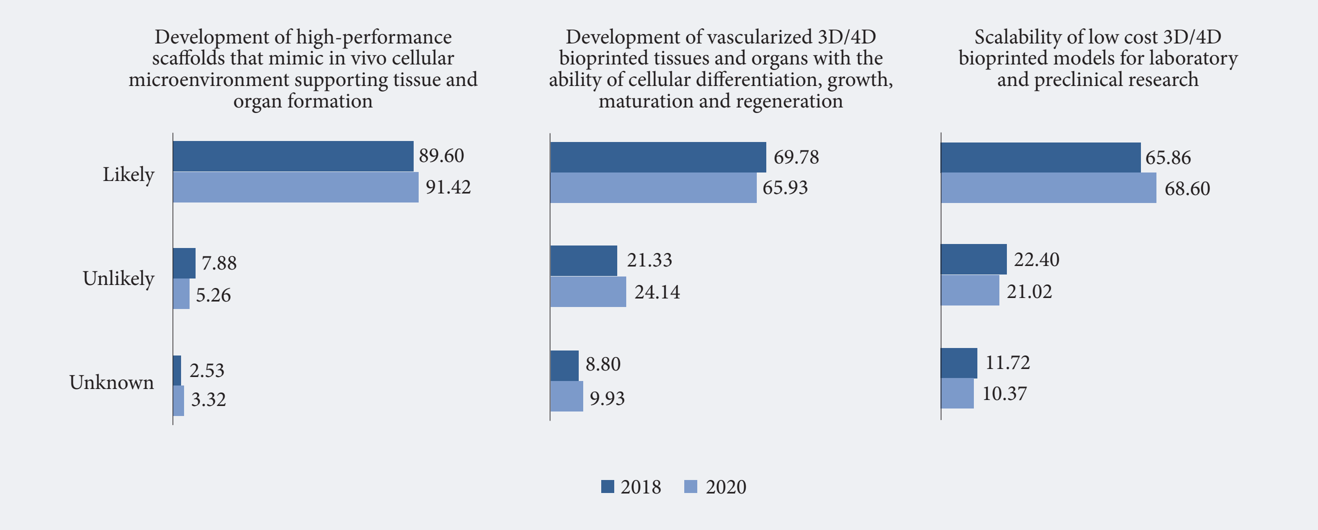
Most W1 researchers (83.9%) considered that, before 2038, 3D/4D bioprinting will likely lead to drug testing models that fit toxicity testing requirements, increasing success in clinical trials. The percentage of W2 researchers who expected this same outcome was a bit higher (85.95%) (Figure 3). The statistical test (marginal homogeneity) confirms that there was no statistical difference between the responses of W1 and W2. According to the Wilcoxon test, in both waves, the statistically predominant response is that 3D/4D bioprinting will lead to the above-mentioned drug testing models before 2038. However, according to the Mann-Whitney U test, in both waves, the level of the respondents' knowledge interferes with the result. Thus, it can be said that some knowledge respondents influenced the outcome related to the period in which these drug testing models are likely to occur. In both waves, about 57% of the respondents who believe this outcome is likely before 2038 have some knowledge of 3D and 4D bioprinting applications in the field of tissue engineering.

The respondents' expectations about 3D/4D bioprinting leading to human disease models that fit research requirements were also very similar in W1 and W2. In both waves, about 90% of respondents considered it likely, with over 70% expecting it to happen before 2038 (Figure 3). Yet, statistical non-parametric tests show that there is no significant difference between the 2018 and 2020 responses. According to the Wilcoxon test, in both waves, the statistically predominant response is that 3D/4D bioprinting will lead to those human disease models before 2038. In both waves, the Mann-Whitney U test indicated that some knowledge respondents' interfered with the results. Of those who believe these human disease models would be likely before 2038, over 55% have some knowledge of 3D and 4D bioprinting applications.

Respectively 66.09% and 67.08% of W1 and W2 respondents reported that 3D/4D bioprinting will likely lead to the replacement of animals in research and toxicity testing, with over 40% of them expecting this before 2038 (Figure 3). Although most respondents expect this to be likely at some point in the future, a good number of them do not believe in this outcome. Of all the statements about the future presented to the experts' analysis, this was the one who had the highest percentage of unlikely answers: 28.41% in 2018 and 25.99% in 2020. The statistical results pointed out that there were no changes in the researchers' perception between W1 and W2. According to the Mann-Whitney U test, in W1, the level of respondents' knowledge does not interfere with the survey results. In W2, for its turn, some knowledge respondents had a statistically significant influence on the result. Overall, according to the Wilcoxon test, the expectation is that 3D/4D bioprinting will lead to animal replacement in research and toxicity testing.

We presented the respondents to five scientific, technological challenges for which 3D/4D bioprinting offers great promise, asking them about the likelihood of these challenges being overcome before 2038 (Figure 4 and Figure 5). High-resolution and high-speed 3D/4D bioprinters compatible with a wide range of biocompatible materials are expected to be developed in up to 18 years according to over 90% of respondents of both waves (Figure 4). High-performance bioinks capable of supporting cell proliferation, differentiation, and

Figure 5. **Likelihood of Scientific and Technological Challenges Being Overcome until 2038 — part 2 (share of responses, %)**



tissue/organ production we also considered likely before 2038 to 87.55% of W1 respondents and 91.60% of W2 respondents (Figure 4). For both statements, there was no statistical difference in W1 and W2 responses and, for both waves, the level of the respondents' knowledge does not interfere with the survey results. The Wilcoxon non-parametric test shows that, in both waves, the statistically predominant response is that these bioprinters and bioinks will likely occur.

The last three challenges are depicted in Figure 5. In both waves, over 90% of respondents considered that the development of high-performance scaffolds that mimic in vivo cellular microenvironment supporting tissue and organ formation is likely to happen until 2038. As for the development of vascularized 3D/4D bioprinted tissues and organs with the ability of cellular differentiation, growth, maturation, and regeneration, there was, from 2018 to 2020, a decrease in the percentage of respondents who expect this result will occur (from 69.78% in W1 to 65.93% in W2). From W1 to W2, both unlikely and unknown answers increased. This was also the challenge with the highest percentage of unlikely answers (24.14%). Finally, the scalability of low cost 3D/4D bioprinted human models for laboratory and preclinical research was considered likely by more than 65% of respondents of both waves. The percentage of likely answers was slightly higher in W2 (68.60% against 65.88% of W1). From W1 to W2, there was a slight decrease in the percentage of unlikely and unknown answers. Nevertheless, they remain high (a little over 20% and 10%, respectively). This was also the only challenge with more than 10% of unknown answers.

The statement related to the development of vascularized 3D/4D bioprinted tissues and organs was the only one that showed a statistical difference between W1 and W2, according to the marginal homogeneity non-parametric test. The frequency distribution of responses suggests that respondents in W2 were more pessimistic about the development of these bioprinted tissues and organs. To both waves, for all the three statements presented in Figure 5, the Mann-Whitney U test shows that the level of respondents' knowledge does not interfere with the results, and the Wilcoxon test that the statistically predominant response is that they will occur.

Discussion

In the future, fully-functional bioprinted tissues and organs are expected to be translated into clinical practice, being implanted in humans (Gilbert et al., 2018; Gershlak, Ott, 2020), which may lead to the creation of a new market for the commercialization of on-demand patient-specific bioprinted tissues, organs (Gilbert et al., 2018). In line with that, most W1 and W2 respondents expect patient-specific tissues, organs produced on demand before 2038. But for this to become a reality, some key issues need to be addressed. For example, it is uncertain whether bioprinted organs can be patient-specific (Colasante et al., 2016; Faramarzi et al., 2018), or even be produced on demand (Colasante et al., 2016). The production of bioprinted patient-specific tissues, organs still requires improvements in computer-aided design software to better reproduce 3D images, better bioprinting resolution to reproduce original shapes, and the development of tissue-specific biomaterials (Colasante et al., 2016; Ng et al., 2016). For its turn, on-demand production of bioprinted tissues, organs will depend not only on the ability of the technology to bioprint functional organs on a human scale but also on the availability of the bioproducts needed for their production (Mir et al., 2019) and the regulation for their commercialization (Gilbert et al., 2018). If on-demand production of patient-specific tissues, organs will be viable in the future, we can expect a reduction of organs waiting lists (Gershlak, Ott, 2020) and immune rejection, leading to improvements in patients' lives (Loai et al., 2019; Mir et al., 2019).

It is also uncertain if 3D/4D bioprinting can lead to the treatment of patients directly at the wound site (Huang et al., 2017). In both waves, respondents expected this to be a reality before 2038. The concept of in situ (or in vivo) bioprinting refers to a system that could scan a patient's lesion and then print a repair using their cells directly at the wound site (Mehrban et al., 2016; Dias et al., 2020). Such a procedure could prevent the need for subsequent surgical interventions (Huang et al., 2017; Chen et al., 2020) and also reduce the patients' recovery time (Park et al., 2016). Yet, in situ bioprinting still has a long way to go before it can be used by surgeons in operating rooms. Among other things, it needs to be fast, automated, and user-friendly (Dias et al., 2020). So far, in situ bioprinting of skin, bones, and cartilages have been tested and achieved positive results on mice (Albanna et al., 2019), but is not yet available for use in humans (Unagolla, Jayasuriya, 2020).

Due in part to interspecies differences, high failure rates in clinical trials are often related to the use of animals as models of diseases and predictors of toxicity in humans (Rosania, 2013; Balls, 2014; Löwa et al., 2018). To improve success rates in clinical trials and so in drug development, more human-based methods would have to be adopted in basic and preclinical research (Burden et al., 2017a; Löwa et al., 2018). This could be achieved through 3D/4D bioprinting, which is expected to be able to provide drug delivery and human disease models for research and drug testing, reducing risks in clinical trials (Richards et al., 2013; Lukin et al., 2019; Gardin et al., 2020; Mota et al., 2020).

In line with that, most W1 and W2 respondents expect 3D/4D bioprinted drug testing models for toxicity testing and 3D/4D bioprinted human disease models for research to be available before 2038. If these expectations are met, and 3D/4D bioprinted models lead to increased success rates in clinical trials, they may be strong candidates for animal replacement (Weinhart et al., 2019). An example of validation with positive results was made in a 3D bioprinted liver model, which was able to predict the toxicity of Trovafloxacin, a drug that had been previously tested in animals in the preclinical phase and was only rejected in phase III of clinical trials. In this case, the 3D bioprinted model proved to be better than animal testing, and if it had been used instead of animals in the preclinical study, the drug would not have entered the following phases, saving time and money (Peng et al., 2017). Thus, if bioprinted models can predict efficacy and toxicity better than animals in preclinical research, we can expect higher success rates in clinical trials (Charbe et al., 2017; Peng et al., 2017) and thus an increase in demand for 3D/4D bioprinted models to replace animal, especially by pharmaceutical companies that are already leading investments in this field (Fonseca et al., 2020).

Although promising, 3D/4D bioprinting still has to overcome a variety of scientific and technological challenges before reaching its full potential (Mao et al., 2020). While the production of less sophisticated human tissues has already proved feasible (Garreta et al., 2017; Stratton et al., 2018; Chen et al., 2020; Matai et al., 2020), the production of more complex functional organs is not there yet (Mir, Nakamura, 2017; Stratton et al., 2018; Wang et al., 2020b). While some organs, like the skin, with a flat structure and a few different cells, are simpler to be built, organs as the kidney, with multiple regions, multiple shapes, and about thirty different cell types, are much more complex to build (Jorgensen et al., 2020). Unlike less sophisticated organs – skin, cartilage, and bones, for example –, complex functional organs – such as kidneys, heart, and liver – requires high-performance scaffolds (Brunello et al., 2016) and vascular networks (Mohanty et al., 2016), whose development is still considered a great challenge today (Unagolla, Jayasuriya, 2020; Wang et al., 2020b). Scaffolds are biocompatible structures that provide an environment where cells can attach and grow (Brunello et al., 2016). Yet, it is not clear which biomaterials and bioprinting methods are most suitable for scaffolds (Tarassoli et al., 2018). At present, scaffolds lack porosity and perfusion, compromising cell growth and differentiation (Brunello et al., 2016), affecting vascularization (Wang et al., 2020a). Such shortcomings in scaffold development hamper the capacity of artificial human tissues and organs to stay alive for longer periods (Vries et al., 2015). Most W1 and W2 respondents considered the development of high-performance scaffolds likely before 2038. Complementarily, bioprinting approaches that seek to produce tissues and organs without the use of scaffolds are also under development. By avoiding problems such as material biocompatibility, the mismatch between scaffold degradation and the growth of the cells that should replace it, and the barriers to the permeability of oxygen, nutrient, and metabolic waste (Khoshnood, Zamanian, 2020).

Scaffold-free bioprinting is also being considered a promise, including for better vascularization of bioprinted tissues and organs (Heinrich et al., 2019; Unagolla, Jayasuriya, 2020). So far, these methods have been used mainly for bioprinting smaller tissues. In part, this is because scaffold-free pre-print preparations are more complex, making them more time-consuming and expensive (Gardin et al., 2020; Khoshnood, Zamanian, 2020). The choice between scaffold-based or scaffold-free methods is based on the desired application (Khoshnood, Zamanian, 2020). Overall, scaffold-based methods are suitable for large, cell-homogenous, matrix-rich tissues, while scaffold-free methods are used for small, cell-heterogeneous, matrix-poor tissues (Alghuwainem et al., 2019). Vascular networks are microchannels of blood vessels and capillaries (Vanderburgh et al., 2017), which are required for cell growth and regeneration since they conduct nutrients and oxygen among the tissues

(Mohanty et al., 2016). Keeping cells alive demands the integration and maturation of vascular networks (Zhang et al., 2020). Today, 3D/4D bioprinting is not fully able to build complex vascular networks capable of performing natural cellular activities (Zhang et al., 2020) and support the production of more complex organs (Zhao et al., 2016). Vascularization and cells need to be bioprinted together, at the same speed, to prevent tissue death (Leberfinger et al., 2019). Also, current bioprinting methods face problems with the bioprinting of hierarchical vascular networks that contain capillaries, vessels and arteries together with other tissues (Murphy et al., 2020; Wang et al., 2020b), and most of them can only print vessels (Leberfinger et al., 2019). According to most respondents of both waves, we can expect the challenge of network vascularization to be overcome before 2038.

The 5D bioprinting has recently emerged as a new technology to create vascularized models (Foresti et al., 2020). It is an evolution of 3D/4D bioprinting, which allows the bioprinting of more complex systems with curved shapes (Kumar et al., 2019). The 5D bioprinting is performed at five different angles by rotating print heads – while 3D/4D bioprinting uses a print head at a fixed angle (Ahmad et al., 2019), allowing the bioprinting of more complex and personalized structures (Dey, Ozbolat, 2020). Yet, none of the mentioned possibilities related to the use of 3D/4D bioprinting can be achieved without improvements in bioprinter and bioink technologies. Bioprinters use fluids containing biomaterials and/or living cells. Known as bioinks, they range from hydrogels (using alginate, collagen, fibrin, gelatin methacrylate) to cell aggregates, microcarriers, and decellularized matrices (Whitford, Hoying, 2016; Hospodiuk et al., 2017; Gungor-Ozkerim et al., 2018). Today, the most common bioprinting techniques are inkjet bioprinting, extrusion bioprinting, laser-assisted bioprinting (Sears et al., 2016; Vijayavenkataraman et al., 2018; Dias et al., 2020; Zhang et al., 2020), which are still time-consuming and labor-intensive (Duan, 2017). In the future, high-resolution and high-speed 3D/4D bioprinters compatible with a wide range of biocompatible materials are expected to be developed (Park et al., 2016; Heinrich et al., 2019). In line with that, more than 90% of W1 and W2 respondents considered this development likely before 2038. High-performance bioinks capable of supporting cell proliferation, cell differentiation, and tissue/organ production are also expected (Mosadegh et al., 2015; Albritton, Miller, 2017; Huang et al., 2017; Mori et al., 2018). In both waves, more than 87% of respondents reported that bioink technology will likely have reached this level of development before 2038. Essentially, the biological functionality of bioprinted constructs is dependent on bioinks having such qualities (Murphy et al., 2020). The absence of high-performance bioinks limits progress in the field of tissue engineering and thereafter the translation of research results to clinical practice (Mori et al., 2018). In an ideal set-up, the bioprinters of the future will be able to combine different bioinks at a speed that enables vascularization, cell growth, and differentiation, allowing tissues and organs to be bioprinted on a larger scale (Dias et al., 2020).

The adoption and diffusion of 3D/4D bioprinted human models in research laboratories not only requires improvements in methods, bioprinters, and bioinks, but also the scalability of low-cost tissues (Tarassoli et al., 2018; Weinhart et al., 2019). Although this was the challenge with the highest percentage of unknown answers, most of the respondents of the two waves expect it to be overcome by 2038. The scalability of low-cost tissues is not a problem when bioprinting a single organ for a patient, but it may be for applications that require multiple constructs for testing, such as preclinical research (Daly et al., 2017). Current bioprinting processes are time-consuming and costly (Wang et al., 2020b), but are the most promising to produce tissues and organs on a larger scale (Correia Carreira et al., 2020), and at low cost (Heinrich et al., 2019).

Final remarks

This study presented the results of a two-wave global survey of tissue engineering-related researchers about the future of 3D/4D bioprinting on biomedical research, drug testing, and medicine. Also, it assessed changes in respondents' expectations between the waves performed in 2018 and 2020. For most of the statements presented to respondents, we can see a growth in optimism from W1 to W2 as it increased the rate of those who reported that it was expected to occur 'before 2038'. The increase in optimism may, perhaps, be related to scientific and technological advancements in the field of tissue engineering over the past two years, allowing respondents to have a clearer view of what the future might look like. In summary, the results suggest that we can expect 3D/4D bioprinted tissues, organs either for implantation in humans or for research and toxicity testing in less than two decades. If the future confirms these expectations, we will probably see the emergence of a new market for the commercialization of bioprinted products, and perhaps a solution to both the problem of organ shortage and adverse drug reaction. As such, these technology-driven changes can have a strong impact not only on the practice of biomedical research, drug testing, and medicine but also on healthcare and public health as a whole. Assuming that the influence of technology on the health sector tends to increase over time, preparing for the future is a necessity for those involved not only in research, clinical practice, or technology management, but also for those responsible for healthcare delivery and for developing and implementing public health policies.

The type of study we performed can be considered a narrow TF (Mota et al., 2021) as opposed to the broader TF studies, best known as fully fledged foresight studies (Miles, 2010). Despite a lack of participatory orientation and policy-relatedness (Miles, 2010), their narrower scope makes them better suited for the study of a given technology (Mota et al., 2021). From this perspective, we offer to the foresight community a feasible and low-cost method of finding, collecting, and consulting a large number of experts from all over the world, which can benefit new future-oriented studies. Therefore, we hope our method to contribute to new studies aimed not only at foreseeing the future from expert opinions but to comparing their expectations over time. Thus, generating information that can keep track of scientific and technological developments.

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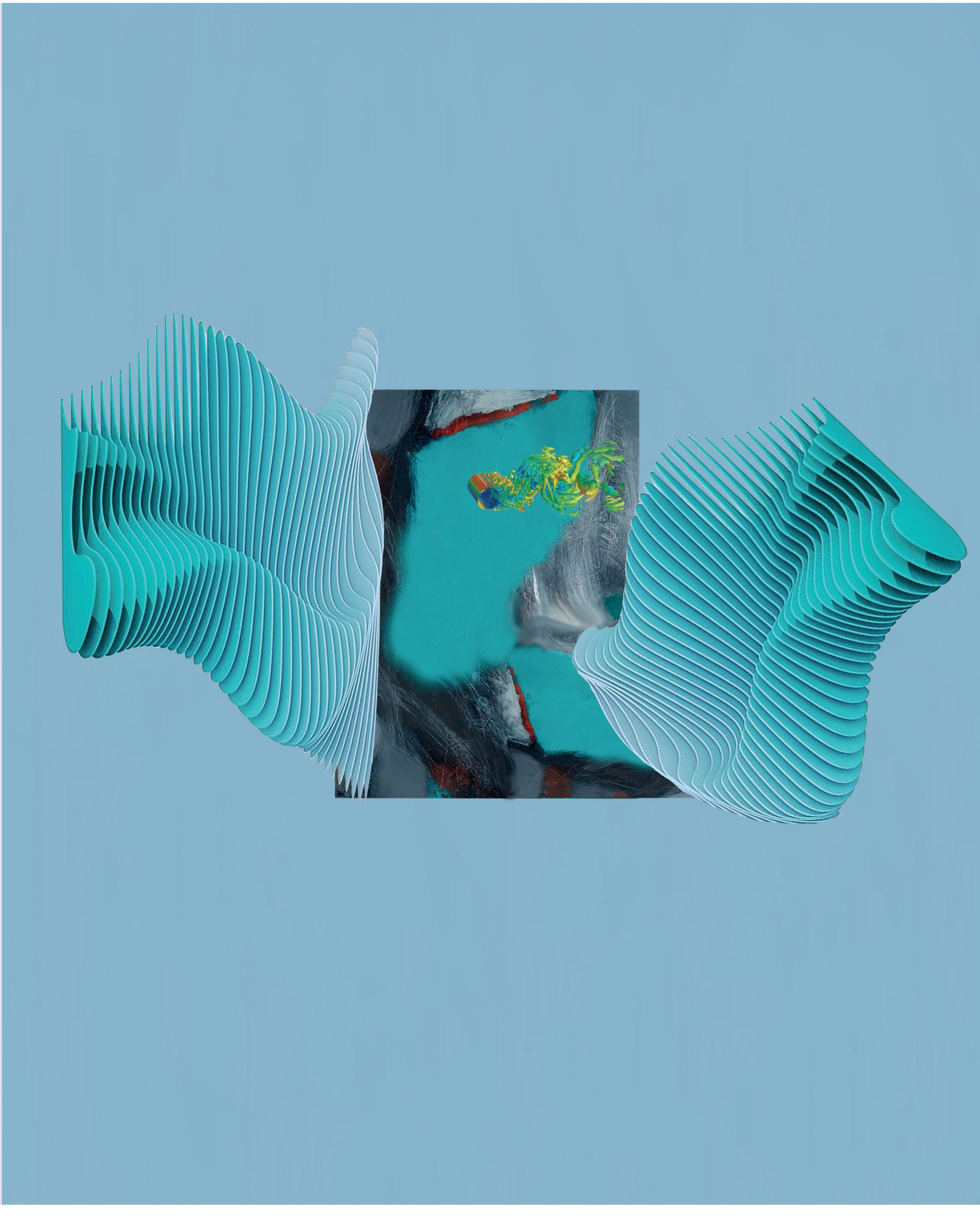
KNOWLEDGE-INTENSIVE BUSINESS SERVICES INDUSTRY



Patterns of Knowledge-Intensive Business Services Use Across Europe

Nikolay Chichkanov
Research Fellow, nchichkanov@hse.ru

Institute for Statistical Studies and Economics of Knowledge (ISSEK), National Research University Higher School of Economics, 11, Myasnitskaya str., Moscow, 101000, Russian Federation

Abstract

This paper examines the structure and the relevance of knowledge-intensive business services (KIBS) consumption for different industries. The research is based upon the analysis of national input-output tables for European countries presented in the last release of the World Input-Output Database (WIOD). The dataset allows for the identification of both the largest and the most intensive sectoral users of KIBS among different manufacturing, market services, and all other industries. The results confirm that the KIBS subsectors are very heterogeneous; patterns of consumption substantially differ across the six different types of KIBS that the data distinguish. It is suggested that these differences may be explained by the existence of specific synergies between each type of KIBS and some of the consuming industries.

Keywords: knowledge-intensive business services; input-output tables; European countries; patterns of consumption

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Introduction

The direct contribution of knowledge-intensive business services (KIBS) to value added and employment is still growing in both advanced and emerging economies (Miles et al., 2018; Chichkanov et al., 2021). This continuing growth of KIBS is fueled by the increasing demand for these services resulting from increasing technological complexity and outsourcing opportunities (Heirati et al., 2016). KIBS are important sources of knowledge for other companies which makes them important actors in national and regional innovation systems (Muller, Zenker, 2001; Doloreux, Gomez, 2017; Shearmur, Doloreux, 2019).

KIBS industries have been empirically found to be highly innovative. Gotsch et al. (2011) reported that KIBS outperform manufacturing and the economy as a whole in terms of both the share of innovative firms and the share of firms engaged in research and development (R&D) activities. Similarly, Behrens et al. (2017) found that knowledge-intensive services have a higher share of innovation-active firms than most other industries except for some R&D-intensive manufacturing sectors. KIBS firms are characterized by a wide range of innovation patterns and strategies in terms of external knowledge sourcing approaches (Rodriguez et al., 2017), appropriability mechanisms (Miozzo et al., 2016), obstacles being faced (Amara et al., 2016), etc. However, KIBS may also have an impact upon the innovation-related behavior of their clients by acting as facilitators (supporting the innovation processes of the client firm while the solution is not being originated from KIBS or transferred from other sources), carriers (transferring the existing innovative solution from other firms or industries) and sources (playing a key role in initiating and developing an innovative solution) of innovation (den Hertog, 2000).

As KIBS consumption is related to the innovativeness of their clients, patterns of such consumption are quite widely explored at the firm level (Shearmur, Doloreux, 2013; D'Antone, Santos, 2016). However, much less is known about patterns of KIBS consumption at the industry level although their use of KIBS may be expected to vary significantly as different industries confront various business problems to different degrees. An existing lack of research in this area may also restrict the effectiveness of the supportive initiatives aimed at stimulating innovation activities through the consumption of KIBS as they may not reach the targeted industries. Trying to fill this gap, this paper aims to explore how KIBS are consumed at the industry level and map out the existing distinctive patterns of KIBS use across the economy. To do so it employs the most recent release of the World Input-Output Database, focusing on European Union (EU) countries which allows for the examination of business services in a more disaggregated way than possible in most of earlier studies (Stehrer et al., 2012).

The next section briefly reviews relevant studies dealing with KIBS consumption at the industry level. After describing data and methods, the research results are presented and discussed. The final part summarizes key findings and outlines implications for further work.

Literature Review

Research interest in the examination of the sectoral patterns of services consumption was fueled mostly by the exploration of the dramatic rise of service industries (and business services (BS[1]) in particular) that occurred in recent decades. For example, Savona & Lorenz (2006) provided an empirical analysis of the structural changes in advanced OECD economies from the end of the 1960s to the end of the 1990s, finding the key growth drivers of services to be quite different from those of manufacturing. While the real growth of output in manufacturing was driven mainly by increases in final demand, this rapid development of services was fueled by the significant changes in both final and intermediate demand and in KIBS this contribution from the intermediary users was found to be among the highest compared to other industries.

Kox (2002) has analyzed Dutch data, finding that the growth of labor specialization and production 'roundaboutedness' significantly contributed to the growth of BS industries. This study suggested that while in the early 1990s, outsourcing of BS was aimed at the simple replacement of in-house activities, in the late 1990s it became more 'service-upgrading' (especially in the case of more client-specific BS) related to the consumption of high-skilled external inputs. The structure of BS consumption also significantly changed: at the end of the 1970s, more than 40% of such services were consumed by manufacturing, while at the end of the 1990s the largest values were found in BS themselves (more than 20%). In addition, the share of BS in total intermediary inputs was found to reach 50% in BS, 30% in distributive services, 25% in both transportation and storage and communication, exceed 20% in financial services and reach about 17%-18% in manufacturing.

Later Kox & Rubalcaba (2007a, 2007b) extended the analysis to other countries and confirmed that from the mid-1990s the increasing complexity and spe-

[1] In early studies, it was often difficult to distinguish between different types of business services due to the data limitation, so all of them were explored jointly. Although, most business services are typically considered KIBS, it also includes some other services like renting or industrial cleaning.

cialization of labor tend to be more important in explaining BS growth than was the simple transfer of activities from other industries (i.e., outsourcing of services that users would previously have obtained internally). Thus, at the end of the 1990s, the BS industry was itself ranked the first destination sector for BS in the UK and Netherlands, the second in France, Germany and the US, and the third in Italy and Spain. As for other industries consuming BS, the largest shares were found in the manufacturing, public sector and trade, hotel, and catering industry.

Baker (2007) explored the consumption of BS in nine EU countries in the mid-1990s and reported that BS were consumed mainly by manufacturing (28.2%) followed by BS themselves (20.4%), public sector (12.3%), trade and hotels (10.8%), and finance and insurance (8.9%). However, adjusting for the differences in the size of the consuming industries it was found that the largest consumers of BS by far are business services themselves, followed by the finance and insurance sector. The same was found in relation to the share of BS in sectoral intermediate consumption – the most intensive users were BS themselves, finance and insurance, and real estate industries. Although manufacturing industries were found to be the largest consumers of BS in absolute terms, these were also reported to be among the least intensive users.

Di Berardino & Onesti (2018, 2020) employed Pasinetti's "subsystem" approach (Pasinetti, 1988) for the analysis of structural changes in European countries. In an earlier paper, the authors compared the contribution of services to six main different subsystems representing agriculture, manufacturing, public utilities, construction, market and non-market services, respectively. The results indicated that market services (including KIBS) are characterized by the most intensive forward linkages, confirming that these services are mostly 'producer inputs', making important contributions to the production of the other products and services. Regarding the intersectoral linkages, the results confirmed that the highest shares of KIBS were in the market services subsystem (of which KIBS form part), in manufacturing and in construction; the lowest ones were in agriculture and non-market services. In the more recent paper, the authors did not focus on KIBS per se, but the examination of the composition of intermediate services demanded by manufacturing subsystems showed that renting and other business activities (including KIBS) tended to be the most vertically integrated service industry (i.e., KIBS inputs are mostly used for the satisfaction of final demand for different types of manufactured products).

Stehrer et al. (2012) compared the role of KIBS inputs for the high-tech (HT) manufacturing industries, for manufacturing industries in general, and for the total economy in 1995, 2000, and 2005 and reported increasing KIBS shares in intermediate consumption in European countries and the US. In addition, the share of KIBS inputs in HT manufacturing was reported to be higher than in manufacturing in general. This result is in line with Ciriaci & Palma (2016) who employed the subsystem approach to explore the level of KIBS vertical integration into manufacturing industries. The authors confirmed that this level significantly increased between 1995 and 2005 and is also affected by the technological intensity of manufacturing industries, tending to be higher in medium-high-tech and high-tech versus low-tech and medium-low-tech manufacturing industries.

Antonioli et al. (2020) examine changes in the productive structures of the European Monetary Union members' economies in the 2000s and applied the subsystem approach specifically to the analysis of KIBS' role in the economy. They paid special attention to the integration of KIBS in the manufacturing industries in these countries, highlighting the frequent underestimation of their indirect role in satisfying the final demand for other products and services. The authors also compared the integration of KIBS in two different types of manufacturing subsystems regarding their technological intensity – low- and medium low-tech (LMLT) and high- and medium high-tech (HMHT) manufacturing respectively. They found that HMHT manufacturing industries tend to better integrate KIBS while the level of KIBS integration in LMLT manufacturing is lower, but here it was much more stable during the financial crisis.

Although KIBS are often described as a quite heterogeneous industry, not all of the studies discussed above consider this issue. One of the rare exceptions is the study by Baker (2007) who identified six clusters, representing six main types of business services consumers - those who are low (1) and average (2) users of all types of business services; and those who are intensive users of a only specific type of business services – renting (3), computing (4), R&D (5) and other BS (6) respectively. While a possible limitation of this work is that the data employed dealt with different time points for different countries, these results show that the consumption of specific KIBS may significantly differ across industries.

This brief literature review clearly shows that the intermediate demand for business services and KIBS, in particular, has grown dramatically. Subsystem analyses that evaluate the importance of KIBS for different industries' final output show that this is a topic that deserves a more detailed analysis of the differences between patterns of KIBS consumption at the sectoral level. As data with a lower level of aggregation becomes available, there is scope for further investigation of KIBS heterogeneity.

Data & Methods

This research is based on the analysis of the input-output tables and the basics for such an analytical framework emerges from the model developed by Leontief (1936) which has become one of the most widely used tools among economists with the increase of the speed and capacity of computer-based calculations (Miller, Blair, 2009). Nowadays, such an analysis and its extensions are used for various types of research – e.g., evaluation of industrial resilience (Giannakis, Bruggeman, 2015), tracking the value-added trade (Johnson, Noguera, 2017), decomposing the structure of carbon emissions (Su et al., 2017), etc.

The data employed for this paper is taken from the World Input-Output Database (WIOD) (Timmer et al., 2015) and include national input-output tables for 28 EU countries[2] in the industry-by-industry format. The last available version of WIOD, released in 2016, covers each year from 2000 to 2014. The methodology of the database construction was close to that used for the previous version of WIOD, released in 2013 (Timmer et al., 2016).[3] From the point of the current research, the most important extension was the change of the aggregation level from 35 to 56 industries, increasing opportunities to explore the consumption of KIBS not only as a whole but also of the six different types of KIBS separately identified.

The empirical results presented in this research were achieved during the two main stages of the analysis. The first stage was devoted to the exploration of the structure of *direct* KIBS consumption among individual industries. First, for each of the 54 individual industries in each country the share of this particular industry in the total intermediate consumption of KIBS was calculated based on the following formula:

$$\text{Industry share}_i = \frac{\text{Intermediate consumption of KIBS by industry}_i}{\text{Total intermediate consumption of KIBS by all industries in a country}} \qquad (1)$$

Then, for each of these industries a simple mean across 28 EU countries was calculated. Finally, following the arguments by Antonioli et al. (2020) on the necessity for the time partition in such analysis and taking into consideration their findings regarding the changes in the integration of KIBS into manufacturing subsystems after the Great Recession, the calculated mean values were averaged across 2011-2014. The whole procedure was replicated for both KIBS as a whole and for each of the six types of KIBS being separately considered.

The second stage of analysis was devoted to the examination of the relative importance of KIBS in the cost structure of different industries by calculating the ratio of total (both domestic and imported) intermediate consumption of KIBS per 100 units of other intermediate consumption for each individual industry in each country:

$$\text{KIBS/other inputs}_i = \frac{\text{Total intermediate consumption of KIBS by industry}_i}{\text{Total intermediate consumption by industry}_i / 100} \qquad (2)$$

These ratios apply at a national level, and to get a picture of typical patterns of industrial use of KIBS for the EU as a whole, each country's data was weighted according to the share of each industry in the total output of the same industries across all European countries. Following the same logic as for the first stage of the analysis, these values were averaged across the years 2011-2014. This procedure was again replicated for both KIBS as a whole and for each of the six types of KIBS being separately considered.

Results & Discussion

The main units of analysis were the individual industrial sectors that were divided into three subsets to facilitate the presentation of results[4]. The first one covers 19 manufacturing industries, including two high-tech (HT), five medium-high-tech (MHT), six medium-low-tech (MLT) and six low-tech (LT) industries.[5] The second subset includes market services (except KIBS themselves[6]) and includes 17 sectors: three trade-related, five specializing in transportation and storage, three financial industries, three information- and communication-related industries, three service sectors covering real estate, accommodation and food, and administrative and support activities. The third subset unites all other industries not included in the first two groups and covers such industries as agriculture, mining, construction, utilities, education, health, etc.

[2] As the used dataset covers the time span from 2000 to 2014 and data for the UK (no longer a EU member) could also be included in the analysis.

[3] The basic principles and the methodology of WIOD development are presented in Dietzenbacher et al. (2013), while the key benefits of WIOD compared with the other similar databases are discussed in Timmer et al. (2015).

[4] Although some of KIBS may be also consumed by households (e.g. legal services), the share of KIBS output being dedicated to final consumption is quite low so it can be neglected for the current analysis.

[5] This classification is based on the technological intensity and is taken from Eurostat (2021). See: https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Glossary:High-tech_classification_of_manufacturing_industries), accessed 21.08.2021.

[6] Self-consumption of KIBS which represent from 17% (for creative KIBS) to 28% (for IT-related KIBS) consumption of KIBS is not analyzed as its inclusion in the analysis will significantly bias the interpretation of the results.

able 1. **Share of Manufacturing Industries in the Intermediate Consumption of Different Types of KIBS (ordered by the share of industry in total KIBS intermediate consumption, %)**

Consuming industry (NACE Rev.2 Code)	KIBS total	KIBS types					
		J62-63	M69-70	M71	M72	M73	M74-75
Manufacture of food & beverages (C10-12)	3.30	1.66	3.11	1.61	2.31	9.61	2.35
Manufacture of motor vehicles & trailers (C29)	1.46	1.16	1.28	2.13	2.80	1.14	1.56
Manufacture of machinery & equipment nec (C28)	1.29	0.98	1.34	1.46	2.78	0.86	1.44
Manufacture of pharmaceuticals (C21)	1.24	0.77	1.07	0.80	4.91	2.61	0.74
Manufacture of computer & electronic products (C26)	1.17	1.42	1.03	0.63	4.52	1.19	1.12
Manufacture of fabricated metal products (C25)	1.04	0.71	1.13	1.85	0.92	0.59	0.73
Manufacture of coke & refined petroleum products (C19)	0.86	0.40	1.15	0.80	0.57	0.36	1.49
Manufacture of chemicals & chemical products (C20)	0.84	0.57	0.92	0.81	1.49	1.30	0.57
Manufacture of electrical equipment (C27)	0.72	0.58	0.79	0.76	0.88	0.62	0.70
Manufacture of rubber & plastic products (C22)	0.55	0.35	0.77	0.54	0.89	0.47	0.46
Manufacture of other non-metallic mineral products (C23)	0.54	0.37	0.74	0.60	0.49	0.41	0.36
Manufacture of textiles, wearing apparel, leather & related products (C13-15)	0.54	0.37	0.62	0.39	0.64	0.74	0.66
Manufacture of furniture & other manufacturing (C31-32)	0.54	0.39	0.58	0.32	0.72	0.72	0.78
Repair and installation of machinery & equipment (C33)	0.53	0.48	0.54	0.72	0.59	0.23	0.82
Manufacture of basic metals (C24)	0.50	0.41	0.66	0.44	0.61	0.27	0.53
Manufacture of other transport equipment (C30)	0.34	0.28	0.34	0.49	0.50	0.22	0.28
Manufacture of wood & wood-based products (C16)	0.33	0.19	0.49	0.28	0.32	0.26	0.26
Manufacture of paper & paper products (C17)	0.32	0.29	0.35	0.30	0.33	0.36	0.27
Printing & reproduction of recorded media (C18)	0.30	0.33	0.32	0.18	0.28	0.37	0.30
Total Manufacturing	**16.39**	**11.71**	**17.23**	**15.10**	**26.55**	**22.31**	**15.43**

Legend: J62-63 — IT-related KIBS; M69-70 — Professional KIBS; M71 — Architecture and engineering; M72 — R&D services; M73 — Creative KIBS; M74-75 — OPST activities.

Source: own calculations based on WIOD, transposed tables.

As was mentioned above, the first stage of the analysis was devoted to the exploration of the distribution of direct KIBS consumption in absolute terms across different industries while the second part of the analysis was devoted to the exploration of the relevance of KIBS consumption for different industries. In both cases, the analysis was done as for KIBS as a whole and for six different types of KIBS separately: IT-related KIBS (computer programming, consultancy and information service activities, J62-63 NACE Rev. 2 codes); professional KIBS (legal, accounting and management consultancy activities, M69-70); architecture and engineering (including technical testing, M71); R&D services (M72), creative KIBS (advertising and market research, M73), other professional, scientific and technical (OPST) activities including design (M74-75)[7].

The share of manufacturing industries in the total direct consumption of KIBS was found to be about 16% (Table 1). The largest consuming sector was represented by companies specializing in the production of food and beverages (C10-12) who significantly exceed all other manufacturing industries (consumed 3.3% of KIBS versus less than 1.5% consumed by any other industry from the top five KIBS users among manufacturing - motor vehicles & trailers production (C29), production of machinery and equipment not being elsewhere classified (C28) or HT industries represented by the production of pharmaceuticals (C21) and computer and electronic products (26) respectively). The lowest amounts of KIBS are consumed by such industries as manufacturing of wood and wood-based products (C16), manufacturing of paper and paper-based products (C17) and printing and reproduction of recorded media (C19), each of those consumes just about 0.3% of KIBS.

However, when different types of KIBS are being considered separately, the share of manufacturing in their consumption varies from 11.7% for IT-related KIBS (J62-63) to 22.3% for creative KIBS (M73) and 26.5% for R&D services (M72). This relative 'overconsumption' of these types of KIBS by manufacturing as a whole seems to be driven by the large disparities in their consumption by individual industries. Thus, while the gaps between the most and the least consuming industries for other types of KIBS tend to be less substantial, these gaps

[7] Due to the data limitation, veterinary services that are often not treated as KIBS are included in this category. More details on the classification of KIBS may be found in Schnabl & Zenker (2013) and Miles et al. (2018).

able 2. **Share of Market Services Industries in the Intermediate Consumption of Different Types of KIBS (ordered by the share of industry in total KIBS intermediate consumption, %)**

Consuming industry (NACE Rev.2 Code)	KIBS total	KIBS types					
		J62-63	M69-70	M71	M72	M73	M74-75
Wholesale trade (G46)	7.96	6.13	8.69	4.43	3.48	12.83	6.38
Financial services (K64)	6.37	8.44	9.15	3.08	3.77	3.96	3.41
Retail trade (G47)	4.73	3.30	5.26	2.31	2.09	9.96	4.26
Administrative & support service activities (N)	3.81	3.24	4.49	2.88	2.25	3.04	5.68
Activities auxiliary to finance & insurance (K66)	2.69	2.18	3.44	0.77	0.77	1.00	1.32
Telecommunications (J61)	2.33	4.15	1.75	1.40	1.13	2.93	2.00
Real estate activities (L68)	2.07	1.06	2.82	3.05	2.92	1.41	1.35
Warehousing & support activities for transportation (H52)	1.77	1.74	1.82	2.43	1.88	1.60	1.56
Accommodation & food service activities (I)	1.36	0.99	1.73	0.88	0.90	1.73	1.45
Insurance, reinsurance & pension funding (K65)	1.36	2.46	1.22	0.74	0.67	1.43	1.81
Trade & repair of motor vehicles and motorcycles (G45)	1.28	0.98	1.28	0.64	0.58	3.08	1.00
Land transport & transport via pipelines (H49)	1.24	1.57	1.34	1.34	1.22	0.75	1.08
Publishing activities (J58)	0.92	1.20	0.68	0.49	0.93	1.48	1.73
Motion picture, video & TV programme production, sound recording & music publishing, broadcasting (J59-60)	0.76	1.20	0.65	0.39	0.34	1.19	1.25
Air transport (H51)	0.46	0.69	0.38	0.25	0.39	0.40	0.82
Water transport (H50)	0.45	0.34	0.53	0.17	0.44	0.65	0.32
Postal & courier activities (H53)	0.34	0.73	0.25	0.28	0.17	0.34	0.24
Total market services	**39.94**	**40.40**	**45.48**	**25.53**	**23.92**	**47.79**	**35.64**

Legend: J62-63 — IT-related KIBS; M69-70 — Professional KIBS; M71 — Architecture and engineering; M72 — R&D services; M73 — Creative KIBS; M74-75 — OPST activities.

Source: own calculations based on WIOD, transposed tables.

tend to be quite high in the case of both creative KIBS (M73) and R&D services (M72). The former is much more consumed by the industry producing food and beverages (C10-12) which consume about 9.6% of the total amount of these services, while all other manufacturing industries together consume just only 12.7%. The latter is much more consumed by two high-tech manufacturing industries: those related to the production of pharmaceuticals (C21) and computer and electronic products (26) who consume 4.9% and 4.5% of R&D services, respectively, which is more than 1.5 times higher than the next large R&D-consuming industry which is manufacturing of motor vehicles and trailers (C29).

The largest users of KIBS, consuming about 40% of these services, are market services industries, such as transport, telecommunications or administrative support services (Table 2). In general, most (but not all) of these industries tend to be bigger consumers of KIBS than manufacturing ones, and this group includes four of the five largest users of KIBS in the whole economy - wholesale (G46) and retail (G47) trade, financial services (K64) and administrative and support services (N). The lowest shares of KIBS consumption among market services are observed in transportation and storage industries – air (H51) and water transport (H50), postal and courier activities (H53).

However, the patterns of KIBS consumption by market services vary across different types of KIBS. Thus, all together market services industries consumed about a half of professional (M69-70) and creative (M73) KIBS, but only a quarter of technological ones like architecture and engineering (M71) and R&D services (M72) - being even smaller absolute consumers of R&D services than manufacturing. As was observed in manufacturing, the KIBS in most demand from the market services tend to display much higher gaps between the largest and the smallest users than do those types that are less demanded. For instance, the two largest user industries account for about 18% of the total consumption of professional KIBS (M69-70) (compared to 28% being contributed by all other market services industries), and about 23% (vs 25%) of creative KIBS (M73). In contrast, the consumption of R&D services (M72) or architecture & engineering (M71) is not so significantly skewed towards the most consuming industries.

About 21% of KIBS is consumed by all other industries like construction, utilities or agriculture (Table 3). Among these industries, the largest KIBS user is construction (F) which consumes about 6.9% of KIBS, followed by public administration and defense (O84, 3.4%) arts, entertainment and recreation (R-S, 3.4%) and human health (Q, 1.9%)

able 3. **Share of Other Industries in the Intermediate Consumption of Different Types of KIBS (ordered by the share of industry in total KIBS intermediate consumption, %)**

Consuming industry (NACE Rev.2 Code)	KIBS total	KIBS types					
		J62-63	M69-70	M71	M72	M73	M74-75
Construction (F)	6.85	2.09	3.61	23.76	4.33	1.61	3.39
Public administration & defence (O84)	3.43	5.16	3.55	3.05	3.27	1.68	5.12
Arts, entertainment, recreation & other activities (R-S)	3.38	4.18	2.51	1.59	3.55	4.96	6.20
Human health & social work activities (Q)	1.93	1.88	2.06	1.50	6.60	1.42	2.38
Electricity, gas, steam & air conditioning supply (D35)	1.75	1.73	2.31	2.15	1.10	0.67	1.57
Education (P85)	1.15	1.47	0.97	0.82	2.14	0.76	3.05
Crop, animal production, hunting & related services (A01)	0.93	0.46	0.44	0.72	1.78	0.27	6.32
Sewerage, waste collection, treatment & disposal activities, materials recovery & remediation activities, etc. (E37-39)	0.78	0.57	0.78	1.33	0.61	0.42	1.02
Mining & quarrying (B)	0.43	0.27	0.42	0.84	0.31	0.21	0.59
Water collection, treatment & supply (E36)	0.24	0.26	0.22	0.37	0.19	0.11	0.41
Forestry & logging (A02)	0.18	0.15	0.25	0.16	0.12	0.09	0.21
Fishing & aquaculture (A03)	0.02	0.01	0.04	0.01	0.04	0.01	0.03
Total other industries	21.09	18.23	17.15	36.28	24.04	12.21	30.28

Legend: J62-63 — IT-related KIBS; M69-70 — Professional KIBS; M71 — Architecture and engineering; M72 — R&D services; M73 — Creative KIBS; M74-75 — OPST activities.

Source: own calculations based on WIOD, transposed tables.

industries. The smallest users include such industries like water collection, treatment and supply (E36), forestry and logging (A02) and fishing and aquaculture (A03) that are not only the smallest KIBS users among the considered set of 'other' industries but also among all industries included in the two other subsets.

Each of the four largest users of KIBS among 'other' industries tends to be ranked among the largest users of each of the individual types of KIBS; but each of them also has one or two specific types of KIBS that it is outstanding compared to other industries in this group. Thus, construction (F) is the very much largest user of architecture and engineering services (M71) - not only among the 'other industries' group but also among all other industries of the economy. Public administration and defense (O84) is one of the largest users of IT-related KIBS (J62-63), while the arts, entertainment and recreation industry (R-S) consumes quite a high share of creative KIBS (M73), as well as of OPST services (M74-75). The human health industry (Q) is the largest user of R&D services (M72), while crop, animal production and hunting (A01) is found to be a large user of OPST services (M74-75). This result could well reflect data limitations: it is impossible to differentiate between KIBS activities (i.e. design services) and activities that are only arguably KIBS (i.e. veterinary services - extremely relevant for agriculture) that are included in the M74-75 category.

The results presented in Tables 1-3 provide an overview of the structure of the direct consumption of KIBS as well as of different types of KIBS. First, the results indicate that the largest users of KIBS (in absolute terms) in the EU countries are market services industries that include four of the five largest KIBS consumers among the individual industries (except for the KIBS themselves). Second, in most cases, the absolute consumption of KIBS seems to be associated either with overall industry size (larger industries consume more of each type of KIBS compared to smaller ones) or with the overall propensity toward KIBS consumption (those industries that consume more (less) of one type of KIBS also consume more (less) of other types of KIBS). Thus, those industries being classified as large (small) absolute consumers of one type of KIBS tend to occupy fairly close positions in the same ranking for other types of KIBS.

However, some strong disparities in the distribution of the individual industries' shares in KIBS consumption emerge when different types of KIBS are separately considered. These disparities are probably driven by the existence of specific synergies between some types of KIBS and some specific industries. For example:

- financial services are the largest users of both IT-related and professional KIBS. The latter may reflect the high relevance of accounting, auditing and legal services for the financial industry, while the former – the rapid development of financial technologies.
- architecture and engineering services are highly relevant for the construction industry – this outstrips all other industries (including engineering and architectural services themselves) in terms of the absolute amount of consumption

able 4. **KIBS/Other Inputs Ratio in Manufacturing Industries (per 100 units of other inputs, ordered by ratio for KIBS in total)**

Consuming industry (NACE Rev.2 Code)	KIBS total	KIBS types					
		J62-63	M69-70	M71	M72	M73	M74-75
Manufacture of pharmaceuticals (C21)	13.07	1.98	4.04	1.79	1.48	3.24	0.54
Manufacture of computer & electronic products (C26)	8.70	2.05	2.78	1.70	0.61	0.96	0.60
Printing & reproduction of recorded media (C18)	7.55	1.47	3.24	0.84	0.20	1.26	0.54
Manufacture of other transport equipment (C30)	7.46	1.34	2.51	2.56	0.21	0.45	0.39
Manufacture of electrical equipment (C27)	6.78	1.13	2.78	1.76	0.10	0.61	0.40
Manufacture of machinery & equipment nec (C28)	6.74	1.11	3.23	1.36	0.21	0.43	0.40
Manufacture of furniture & other manufacturing (C31-32)	6.59	1.00	2.28	0.65	0.28	1.46	0.91
Repair and installation of machinery & equipment (C33)	6.50	1.10	2.86	1.65	0.11	0.43	0.36
Manufacture of other non-metallic mineral products (C23)	6.43	0.72	3.11	1.61	0.10	0.57	0.31
Manufacture of textiles, wearing apparel, leather & related products (C13-15)	5.82	0.88	2.18	0.74	0.07	1.06	0.89
Manufacture of food & beverages (C10-12)	5.43	0.52	2.09	0.48	0.07	2.02	0.25
Manufacture of chemicals & chemical products (C20)	5.33	0.78	2.05	0.95	0.19	1.12	0.24
Manufacture of rubber & plastic products (C22)	5.14	0.64	2.38	1.19	0.09	0.56	0.28
Manufacture of motor vehicles & trailers (C29)	5.05	0.77	2.06	1.00	0.17	0.72	0.33
Manufacture of fabricated metal products (C25)	4.86	0.82	2.12	1.13	0.06	0.40	0.33
Manufacture of coke & refined petroleum products (C19)	4.17	0.27	3.14	0.43	0.03	0.19	0.10
Manufacture of paper & paper products (C17)	3.88	0.63	1.71	0.73	0.05	0.54	0.23
Manufacture of wood & wood-based products (C16)	3.49	0.47	1.64	0.77	0.05	0.35	0.23
Manufacture of basic metals (C24)	2.96	0.46	1.68	0.50	0.04	0.14	0.14

Legend: J62-63 — IT-related KIBS; M69-70 — Professional KIBS; M71 — Architecture and engineering; M72 — R&D services; M73 — Creative KIBS; M74-75 — OPST activities.

Source: own calculations based on WIOD, transposed tables.

of such services, and indicates the dependence of construction projects upon these inputs.

- R&D services are more demanded by manufacturing (especially by HT manufacturing) than by services. However, its largest user is the human health and social work activities industry which probably reflects the presence of clinical trials and biopharmaceutical R&D in this category of KIBS.
- creative KIBS represented by advertising and marketing services are – not surprisingly - significantly demanded by consumer-facing industries like trade, arts and entertainment, production of food and beverages and finance.

Table 4 presents the results of the analysis of KIBS importance (measured by the KIBS/other inputs ratio) for a subset of manufacturing industries. In general, the higher importance of KIBS for those manufacturing sectors with higher technological intensity was only partially confirmed. On the one hand, the intermediate consumption of KIBS as a whole is significantly more important for HT manufacturing (C21 and C26) and large parts of MHT manufacturing (C27-C28, C30), compared to most LT and MLT manufacturing industries. On the other hand, printing and reproduction of recorded media (C18) typically considered a LT industry and earlier found to be the smallest user of KIBS among manufacturing, was found to be ranked the third most 'KIBS dependent' industry (probably, due to the high relevance of IT-related equipment and design activities). Another industry traditionally considered as LT - the manufacturing of furniture (C31-32) - was also found to rely on KIBS consumption significantly more than such MHT industries such as manufacturing of chemicals (C20) or motor vehicles (C29) (probably, due to the high importance of the design services included in OPST, M74-75).

The main reason for the differences from the analysis of the direct consumption of KIBS in absolute terms earlier presented relates to the higher relevance on one or other specific KIBS input against others, for specific industries. For instance, both IT-related KIBS (J62-63) and R&D services (M72) were found to be relatively much more important for HT manufacturing, including both pharmaceutical (C21) and computer and electronic products manufacturing (C26). In turn, architecture and engineering services (M71) were reported to be especially relevant for the manufacturing of transport equipment other than motor vehicles (C30), while creative KIBS (M73) receive greater attention from those industries producing goods for final consumption - manufacturing of pharmaceuticals (C26) and food and beverages (C10-12).

able 5. **KIBS/Other Inputs Ratio in Market Services Industries (per 100 units of other inputs, ordered by ratio for KIBS in total)**

Consuming industry (NACE Rev.2 Code)	KIBS total	KIBS types					
		J62-63	M69-70	M71	M72	M73	M74-75
Financial services (K64)	22.18	5.86	11.90	1.17	0.14	1.99	1.12
Administrative & support service activities (N)	19.10	2.80	10.13	2.94	0.19	1.39	1.65
Activities auxiliary to finance & insurance (K66)	18.71	6.21	8.22	1.44	0.12	0.86	1.86
Publishing activities (J58)	18.15	5.69	5.21	1.11	0.57	3.60	1.97
Retail trade (G47)	14.89	2.05	7.24	1.09	0.09	3.46	0.97
Wholesale trade (G46)	14.08	2.24	7.04	1.08	0.12	2.43	1.17
Telecommunications (J61)	13.42	5.16	3.65	1.34	0.11	2.25	0.90
Insurance, reinsurance & pension funding (K65)	13.22	3.23	6.06	1.06	0.09	1.60	1.19
Motion picture, video & TV programme production, sound recording & music publishing, broadcasting (J59-60)	12.92	3.28	4.71	1.41	0.14	2.22	1.16
Trade & repair of motor vehicles and motorcycles (G45)	12.65	2.32	5.02	1.26	0.09	3.13	0.83
Real estate activities (L68)	10.90	0.86	6.97	2.07	0.08	0.35	0.57
Postal & courier activities (H53)	10.82	4.39	3.36	1.09	0.10	1.30	0.57
Warehousing & support activities for transportation (H52)	7.54	1.50	3.51	1.52	0.07	0.51	0.43
Air transport (H51)	6.37	2.26	1.90	0.57	0.15	0.74	0.75
Accommodation & food service activities (I)	6.36	1.21	3.08	0.75	0.06	0.74	0.53
Land transport & transport via pipelines (H49)	5.66	1.48	2.07	1.17	0.10	0.48	0.35
Water transport (H50)	5.18	1.39	2.52	0.57	0.07	0.38	0.25

Legend: J62-63 — IT-related KIBS; M69-70 — Professional KIBS; M71 — Architecture and engineering; M72 — R&D services; M73 — Creative KIBS; M74-75 — OPST activities.

Source: own calculations based on WIOD, transposed tables.

The KIBS/other inputs ratios for market services industries are presented in Table 5. The most relatively intensive users of KIBS as a whole were found to be financial services (K64, K66) and administrative and support services (N) while different types of transport services (H49-H53) and accommodation and food service activities (I) were characterized by the lowest levels of KIBS intermediate consumption compared to the consumption of other inputs. This appears to differentiate services involving a great deal of office-based information work, from services reliant more on unskilled labor and/or on handling physical products.

Substantial differences in the relative importance of KIBS for market services industries are observed when separately examining different types of KIBS. Thus, financial services other than insurance (K64 and K66) were found to be the most 'dependent' users of both IT-related (J62-63) and professional (M69-70) KIBS while being 'medium-dependent' users of other types of KIBS. Similarly, publishing (J58) and telecommunication (J61) industries are characterized by the high levels of importance of IT-related KIBS (J62-63) while trade-related industries (G45-G47) intensively use creative KIBS (M73). The most specialized KIBS for the market services industries were found to be architecture and engineering services (M71) and R&D services (M72). The former are used particularly intensively by administrative and support services (N) and real estate (L68) industries; the latter are intensively used by the publishing industry (J58) as compared to other sectors in the considered subset.

The analysis of the KIBS/other inputs ratios of other industries is presented in Table 6. Public administration and defense (O84), arts, entertainment and recreation (R-S) and education (P85) are found to be the most intensive users of KIBS as a whole and also of both IT-related (J62-63) and professional (M69-70) KIBS. The public administration and defense sector (O84) is also characterized by a quite high level of importance of consumption of each of the other types of KIBS; the arts, entertainment and recreation (R-S) and education (P85) industries are both characterized by quite high importance of the consumption of OPST services (M74-75). However, these two industries differ in the relative importance of the consumption of the other two types of KIBS – while the arts, entertainment and recreation industry (R-S) tend to be among the most relatively intensive users of creative KIBS (M73), the education industry (P85) is ranked as the most relatively intensive user of R&D services (M72).

Another relatively intensive user of R&D services (M72) is the human health industry (Q) which significantly outperforms other considered industries (except for education) here. It may be also concluded that architecture and engineering services able 6. **KIBS/Other Inputs Ratio in Other Industries (per 100 units of other inputs, ordered by ratio for KIBS in total)**

Consuming industry (NACE Rev.2 Code)	KIBS total	KIBS types					
		J62-63	M69-70	M71	M72	M73	M74-75
Public administration & defence (O84)	13.82	3.21	5.97	2.34	0.20	0.88	1.23
Arts, entertainment, recreation & other services (R-S)	13.32	3.29	5.36	1.51	0.15	1.69	1.32
Education (P85)	12.18	3.22	4.64	1.50	0.35	0.59	1.88
Sewerage, waste collection, treatment &disposal activities; materials recovery & remediation activities, etc. (E37-39)	10.78	1.96	3.74	3.69	0.14	0.49	0.78
Mining & quarrying (B)	9.59	1.29	4.47	2.73	0.13	0.45	0.52
Water collection, treatment & supply (E36)	9.36	1.92	3.33	2.92	0.11	0.46	0.61
Human health & social work activities (Q)	7.92	1.76	3.66	0.98	0.33	0.41	0.78
Construction (F)	7.68	0.67	2.44	3.88	0.08	0.24	0.37
Electricity, gas, steam & air conditioning supply (D35)	4.65	0.75	2.25	1.13	0.05	0.25	0.23
Forestry & logging (A02)	4.19	0.58	2.07	0.69	0.12	0.30	0.42
Crop, animal production, hunting & related services (A01)	3.19	0.19	0.95	0.40	0.13	0.11	1.40
Fishing & aquaculture (A03)	2.96	0.28	1.88	0.18	0.18	0.17	0.27

Legend: J62-63 — IT-related KIBS; M69-70 — Professional KIBS; M71 — Architecture and engineering; M72 — R&D services; M73 — Creative KIBS; M74-75 — OPST activities.

Source: own calculations based on WIOD, transposed tables.

(M71) are most necessarily required by 'land-based' industries with large technical facilities - construction (F) and sewerage, waste collection, treatment and disposal activities (E37-39) followed by water collection (E36) and mining (B). Finally, agricultural industries (A01-A03) were found to have the lowest levels of KIBS/other inputs ratios, even taking into consideration the idea that crop and animal production and hunting industry (A01) is a quite intensive user of veterinary services (merged with other OPST services into a single WIOD category (M74-75).

The results presented in Tables 4-6 shed the light on the relevance of KIBS consumption for different industries measured by the ratio of used KIBS inputs to all the other inputs. First, the hypothesis of the higher relevance of KIBS for more technologically-intensive manufacturing industries was only partially confirmed as some low-tech industries were also found to be characterized by quite high relative levels of KIBS consumption. Second, the level of the KIBS/other input ratio tends to differentiate market services with higher levels being observed in industries with higher levels of office-based information work, while lower levels are observed in industries that tend to use less skilled labor. Third, the disparities observed when different types of KIBS are separately considered also supports the hypothesis of the existence of specific synergies between some types of KIBS and some specific industries, like:

- the high relevance of IT-related and especially of professional KIBS for financial industries was fully confirmed, while other industries being relatively more dependent on these services are telecoms (for IT-related KIBS) and administrative and support services (for professional KIBS).
- architecture and engineering services were found to be relatively more important for construction, sewerage and waste collection and management services, production of some transport equipment, but also for administrative services and mining and quarrying industries.
- HT manufacturing industries (the production of pharmaceuticals and computers) are characterized by the highest ratios of KIBS/other inputs consumption in the case of R&D services. In contrast, human health and social work activities industry, which was found to be the largest consumer of R&D services in absolute terms, rely less upon these services and require a much greater number of other inputs.
- creative KIBS represented by advertising and marketing services were found to be relatively more relevant for the publishing industry and for both retail and wholesale trade.

Conclusions

The main goal of this paper was to examine the patterns of KIBS consumption (in terms of its structure and relevance) at the industry level across EU countries. The WIOD data allows for the examination of the consumption of KIBS as a whole and of six different types of KIBS. This is a greater level of disaggregation than most previous studies of KIBS consumption and vertical integration into other sectors could manage. Among the user industries, the largest direct users of KIBS were found to be not manufacturing, but market services industries - in particular financial and trade-related ones. Substantial variations in both the consumption and the relevance of different types of KIBS across different industries were apparent. It was shown that some of the six types of KIBS have some 'core' user industries, characterized by a significantly higher relevance of KIBS consumption relative to other inputs. These findings confirm the high level of heterogeneity across different types of KIBS and highlight the need to use disaggregated data when examining the intersectoral relationship between KIBS and other industries as well as KIBS' role in the economy. In addition, these results suggest that more targeted innovation policy actions may be developed aimed at either supporting the innovative development of those industries consuming different types of KIBS or the growth of KIBS industries through the support of their key consumers.

This paper inevitably features some limitations, which suggest important issues for future research. First, understanding KIBS' evolution can draw upon the analysis of country-level differences in the consumption and intensity of different types of KIBS. On the one hand, it may be useful to compare not only broad groups of countries but also to explore the factors that may explain the existing differences. On the other hand, as the WIOD also contains some data on non-European economies it provides some opportunities for making some comparisons among a wider range of economies.[8] Second, it should be possible to link the consumption of KIBS with other sectoral features, such as their consumption of non-KIBS inputs, their productivity (trends), and the destination of their outputs. Finally, some alternative modes of provision of knowledge services might be examined, for example, those relating sectoral KIBS purchases to sectoral employment of 'KIBS-type' professionals like accountants, lawyers, and so on. Finally, trade in KIBS inputs and outputs could also be a fruitful topic for analysis.

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[8] It may be especially interesting to compare patterns of KIBS consumption in advanced economies and less developed ones, such as BRICS countries. Although WIOD contains some data for emerging non-European economies, the applicability of these data is limited. For instance, the WIOD creators recommended (e.g. Timmer et al., 2016) to use Russian data only for the analysis of the international trade rather than for the analysis of the economy itself due to the outdated nature of the presented data.

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Knowledge-Intensive Social Services as the Basis for the National Social Innovation Systems

Benoît Desmarchelier
Assistant Professor, benoit.desmarchelier@univ-lille.fr

Faridah Djellal
Professor, Faridah.Djellal@univ-lille.fr

Faïz Gallouj
Professor, Faiz.Gallouj@univ-lille.fr

The University of Lille, 42 rue Paul Duez 59000 Lille — France

Abstract

This paper provides theoretical foundations for the existence of national social innovations systems (NSIS) and presents such a system with empirical data. Departing from the activities in France of Ashoka, a large and old service organization, which we label as knowledge-intensive social service (KISS), we build a large and robust social innovation network in France and argue that it represents a credible approximation of the country's NSIS. On this basis, we find differences within the national innovation system (NIS). Indeed, the core of the NSIS involves very few actors emanating from manufacturing or technology-intensive industries, and the coordination between actors seems more bottom-up than in the NIS.

Keywords: national innovation system; knowledge-intensive services; third sector; social innovation

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Introduction

Innovations are introduced by entrepreneurial individuals, but the sustained thrust of innovations requires a whole system of beliefs, payoffs, and supporting institutions (Baumol, 1993; Mokyr 2010). With regards to social innovations, we observe a gap between the literature that focuses on the character of the social entrepreneur (Mulgan et al., 2007; Dacin et al., 2010; Moulaert, MacCallum, 2019) and the fact that social entrepreneurship is becoming commonplace, thereby suggesting the presence of a dedicated innovation system that still needs to be uncovered. An indication of the prevalence of social entrepreneurship is provided by the Global Entrepreneurship Monitor (Bosma et al., 2016). Reviewing 52 countries across the globe, the report highlights that, on average, 3.2% of adults between 18 and 64 years old are in the process of starting a business with a social mission. Adding up the number of people who already operate such a venture, the authors find that 11% of the adults are involved in a social enterprise in the US and Australia. The corresponding figure in Europe and Latin America is around 6% of the adult population. It follows that the appropriate analytical angle should be the social innovation system, rather than the heroic individual. Hence, we developed a systemic view of social entrepreneurship whose key features are presented earlier in Desmarchelier et al. (2020).

Adopting a technological regime framework (Winter, 1984), the authors find that social innovations are getting increasingly routinized due to the activities of a new category of agents, the knowledge-intensive social services (KISS). These are agents from the third sector who assist social entrepreneurs by providing them with knowledge and other resources. A distinctive feature of KISS actors is that they put the social entrepreneurs in contact with other socially minded agents, thereby creating networks aimed at generating social innovations. The network built by Desmarchelier et al. (2020) is small and poorly connected (134 agents and 523 links). Thus, it represents at best a local system of social innovations, which is too fragile to stand as a major social innovation engine at the national level. In addition, their contribution does not provide an explanation for the growth of social entrepreneurship. In this context, the present paper pursues two objectives: (i) providing a theoretical framework of the growth of social entrepreneurship and the emergence of national social innovation systems (NSIS) and (ii) providing a more comprehensive view of such a system than the one proposed in Desmarchelier et al. (2020).

Acknowledging the connecting role of KISS actors, we propose to obtain an overview of the French national system of social innovations by tracking the social innovation projects supported in France by an old and well-established KISS, Ashoka, a US-based non-profit organization promoting social entrepreneurship around the world. We limit the present study to the French case, but using such a global actor could offer the opportunity to trace similar networks in other countries and therefore to carry out comparative studies in the future.

From Innovations to National Systems of Social Innovations

The concept of innovation is well defined: it is the act of putting an invention on the market. In his classical work, Schumpeter (1934) distinguishes between five types of innovations: (i) the marketization of new goods or services, (ii) the implementation of a new production method, (iii) the discovery of a new market, (iv) the discovery of a new source of supply, and (v) a new way to organize an industry. This list is most often taken for granted. Yet, Baumol (1993) expands it with two new categories:

- The "*innovative acts of technology transfer*" (p. 28), which are activities surrounding the replication of foreign technologies. The author, among others (see for instance (Nelson, Pack, 1999; Hobday, 1995), consider that replication in a different context is a type of innovation because it always involves a certain degree of novelty and surmounting many obstacles and uncertainties. Baumol also puts forth that this type of innovation is necessary to account for convergence dynamics among economies.
- A destructive type of innovation in terms of rent-seeking procedures. According to Baumol (1993), these innovations have always been present over the course of human history, but they have been outnumbered by the other, productive, types of innovations in countries where economic growth has taken off.

We believe social innovations could expand Schumpeter's list further. However, defining social innovations proves to be difficult. Indeed, most definitions are making use of the word "social", which poses a circularity problem. For instance, Mulgan (2015) indicates that they are "*innovations that are social in both their ends and their means*". In the same vein, Dacin et al. (2010) list 37 definitions of social entrepreneurs, most of which are relying upon the word "social". In their definition attempt, Krlev et al. (2019) put forth that social innovations respond to citizens' lack of trust in the ability of the market to solve a wide range of social and ecological issues, and Moulaert and Ailenei (2005) highlight that social innovations are solutions aiming at correcting the allocation of resources produced by the market. Assuming that social innovations are emanating from the third sector (Anheier et al., 2019), we can infer that they depart from the profit-seeking motive and that they contribute to modifying society's allocation of resources (financial, medical, educational, relational, or environmental). From this perspective, we propose to define social innovations as reallocation innovations, which do not bow to the profit motive. This new type of innovation can be thought as another expansion of the Schumpeterian listing. Baumol's (1993) contribution to Schumpeter's work goes beyond the addition of elements to the well-known typology of innovations. He adds a theoretical framework to it: to him, all societies past and present are made of a category of risk-taking individuals, who allocate their efforts among the various types of innovations depending upon the society's payoff system. Prior to the Industrial Revolution, rent-seeking innovations were providing safer and greater rewards, in terms of profit and prestige, than the productive types. Mokyr (2010) indicates that the situation changed in England on the eve of the 19th century due to the emergence of a culture of the "*gentleman entrepreneur* " (p. 188). Despite an inadequate banking system, productive entrepreneurship flourished thanks to a virtuous circle between an individual's trustworthiness in business affairs and its social reputation. Going back to social entrepreneurship, we could infer that its recent development might be the reflection of a changing system of beliefs and payoffs. For instance, we note the appearance of new legal forms of non-profit companies, like the benefit corporations in the United States, the community interest companies in the United Kingdom, or the *entreprise solidaire d'utilité sociale* in France.

What Baumol's theoretical hypothesis of the allocation of entrepreneurial efforts reflects is that a sustained innovative dynamic in a specific direction (productive/unproductive, or even social) is the product of a larger system, which might include a set of cultural elements but also institutions governing financial payoffs (for instance, property rights or means to get access to necessary financial and human resources). These norms and institutions are largely country-specific and therefore, in the same way as we speak of national innovation systems (NIS), we believe that we could speak of national social innovation systems (NSIS). A gap in Baumol's theory is that it does not explain how and why payoff systems are changing over time, and therefore why would an NIS emerge at some point in a country's history, or why would an NSIS emerge in recent years? The lack of trust in governments and markets (Krlev et al., 2019) stands as a potential explanation. Moulaert and Ailenei (2005) also points to the gap between growing inequalities on the one hand, and the promises of greater wealth produced by free markets on the other.

Mokyr (2013) answers the question about changes in societies' payoff systems with his concept of cultural entrepreneurs. They are individuals who search for reputational fame by proposing new cultural elements (ideas, values, and beliefs). For the author, such individuals experience a "*cognitive dissonance*" (p. 7) between the set of prevailing beliefs and a large amount of contradictory evidence. Examples of cultural entrepreneurs are famous innovators in the domain of ideas who provoked dramatic changes in the beliefs of their contemporaries: Luther and Calvin, Galileo, Adam Smith, Marx, or Bacon stand as famous examples. The transformative power of these new beliefs comes from the fact that they share three characteristics: they are "normative", "positive", and "prescriptive", that is they are desirable, possible, and formulated in the form of a practical or political agenda. To rephrase the theoretical framework developed so far: due to some cognitive dissonance between observations and society's set of accepted beliefs, cultural entrepreneurs propose new beliefs and changes in the payoff system, which then guide the efforts of risk-taking individuals toward more or less productive innovations.

In the case of social entrepreneurship, there are many advocates of alternative business models, like Bill Drayton, the founder of Ashoka - a non-profit organization supporting social entrepreneurs, or Muhammad Yunus, the promoter of micro-finance and founder of the Grameen Bank. These individuals can be considered cultural entrepreneurs because they produce beliefs that are normative, positive, and prescriptive. Indeed, their social enterprises demonstrate the desirability and feasibility of social ventures, while their conferences, books, and papers incentivize other individuals and political leaders to change their beliefs and the payoff systems so as to make social entrepreneurship more common and rewarding.

The fact that people's values and beliefs have evolved in favor of social entrepreneurship in developed countries is exemplified by the normalization of social entrepreneurship evoked in the introduction of this paper and the appearance of the KISS actors (Desmarchelier et al., 2020). Regarding the changes in the payoff systems, we have highlighted the appearance of new legal forms of companies and there are many policy initiatives supporting social entrepreneurship, like the recent Social Economy Action Plan of the European Commission.[1] In sum, studying social entrepreneurship through the sole lens of the entrepreneurs is incomplete, because it omits the growing influence of the surrounding national system that supports and promotes social innovations. In this context, the objective of the next section is to bring evidence that NSISs do exist.

[1] https://ec.europa.eu/social/main.jsp?catId=1537&langId=en, accessed 07.02.2022.

Mapping a National Social Innovation System

The concept of a national innovation system (NIS) states that a country's performance in terms of innovations is the product of a set of intricate relationships between firms, universities, and government agencies (Nelson, 1993; Freeman, 1995). The national character comes from the history-dependent nature of the actors and their relations. For instance, the US innovation system since the Second World War has been dominated by the defense industry (Mowery, Rosenberg, 1993), while in Japan, the Ministry of International Trade and Industry had a considerable influence upon firms' technological catch-up (Odagiri, Goto, 1993).

From a methodological point of view, contributions in terms of the NIS often consist in presenting data about patents and R&D spending, which are then put into perspective through specific historical and political considerations. Such an identification strategy seems inappropriate in the case of social innovations. Indeed, actors from the social economy are not profit-seeking, and therefore they have no use in patenting. The consequence is a lack of data about social innovations at the national level.

In this context, Desmarchelier et al. (2020) propose an alternative: they depart from a KISS actor, the "*Agence Nouvelle des Solidarités Actives*" (ANSA), and they build a social innovation network from the list of all the innovative projects supported by this actor. The ANSA is a relatively new actor, as it was founded in 2006. We note that this network is too small (134 actors), too disconnected and too dependent on a few actors to stand as a fair picture of a NSIS. Yet, the methodology can be replicated on a larger scale. This is what we propose to do in this section to get an overview of the French NSIS. To uncover the French NSIS, we propose to use an older KISS, Ashoka, a US-based organization aimed at promoting social entrepreneurship around the world. The organization was founded in 1980 by Bill Drayton, who we identified in the previous section as a cultural entrepreneur. We consider Ashoka a KISS actor since it supports social entrepreneurs by helping them in skills building and by integrating them into a peer network. The organization operates in many countries, where it supports local social entrepreneurs, named "Fellows Ashoka".[2] In particular, Ashoka supports 72 "fellows" in France. These are selected by Ashoka for their specific projects, and as such these fellows actually constitute a list of 72 social innovation projects.

able 1. **Excerpt from the Relational Matrix of the Ashoka Network in France**

Organizations	Projects		
	Les petites cantines	Chemins d'avenir	Activ'Action
Ashoka	1	1	1
AG2R	1	0	0
La France s'engage	1	0	1
Fondation de France	1	0	1
Fondation petits frères des pauvres	1	0	0
Fondation St Irénée Lyon	1	0	0
Fond Groupe SEB	1	1	0

Note: The projects supported by Ashoka are recorded in the columns, while the participants appear in the rows.

Source: authors.

The projects' websites usually list all the participating actors, which enables us to build a relational matrix linking actors to the social innovation projects. Since we do not know the financial involvement of the various actors, we use binary numbers: 0 when an actor is not involved in a project and 1 when it participates. An excerpt of this matrix is provided in Table 1. In this table, we observe that many actors are involved in a project named "les petites cantines"[3]. In addition, the actor "Fond Groupe SEB" is also involved in the project "Chemins d'avenir", while the actors "La France s'engage" and "Fondation de France" participate in the project "Active Action". This type of cross-participation acts as bridges between projects, favoring the emergence of a well-connected network of socially motivated actors.

The 72 projects mobilize a total of 1,031 actors. Assuming that participants in a given project are related to one another, we can build a second matrix linking these 1,031 actors together directly.[4] The resulting network is displayed in Figure 1. In this Figure, the vertices represent the actors and every relationship between them is symbolized by a link. Links are not repeated: if two agents are involved in several identical projects, then we still count as only one link. In the Figure, the more central an actor, the more connected it is. Nodes and labels sizes are proportional to the actor's connectivity in the network, and for readability reasons, only the labels of the 50 most connected actors are displayed. Figure 1

[2] The list of all Ashoka Fellows in France can be obtained at the following address: https://www.ashoka.org/fr-fr/fellows-ashoka, accessed 07.02.2022.

[3] "*Les petites cantines*" is a project aiming at reducing people's loneliness by creating participative canteens throughout the country. "*Chemins d'Avenir*" is a mentoring system to provide support and guidance to the youths living in disadvantaged neighborhoods. "*Active Action*" helps the unemployed to gain more confidence in their capabilities, beyond their past job experiences.

[4] The corresponding network files can be obtained freely from the authors upon request.

Figure 1. **Overview of the Ashoka Network in France**

Note: Names are those of the 50 more connected actors in the network.

Source: authors.

Figure 2. **The Social Innovation Network in France when Ashoka has been Removed**

Source: authors.

shows the existence of several clusters of agents, but none is disconnected from the rest of the network and overall, all the actors seem highly connected to one another. The descriptive statistics provided in Table 2 confirm this impression. Indeed, first, the network is made of a single component, and secondly, the path length of 1.909 implies that many actors are in direct contact and that is there is no intermediary between them.

In Desmarchelier et al.'s network (2020), removing the organizing KISS had the effect of splitting the main component into a myriad a smaller and disconnected sub-networks. Figure 2 displays the Ashoka network when Ashoka has been removed. It appears that the network remains highly connected and made of a single component. This observation is confirmed by the Table 2, which shows that the path length is only marginally increased by the removal of Ashoka (2.065 instead of 1.909). At the same time, the average number of links per vertex barely decreases (91.363 instead of 93.272). As a result, we can say that the present social innovation network is way more robust than the one presented in Desmarchelier et al. (2020), and therefore it constitutes better proof of the existence of a French NSIS as well as a better picture of it.

Table 3 provides the list of the 50 most connected actors in the network. All of them are more than twice as connected as the network average (93.272 links on average, see Table 2). This core of highly connected agents is the source of the robustness of the network, even in the hypothetical situation in which Ashoka would cease its activities. They are thus essential for the functioning of our social innovation network and certainly central as well in the French NSIS. Comparing this list with the core of the country's NIS allows one to highlight differences and similarities between the two innovation systems.

To our knowledge, the most recent description of the French NIS is provided by Muller et al. (2009). This system is structured around a few major public research centers: the National Center for Scientific Research (CNRS) which handles fundamental research and several mission-oriented public research

Table 2. **Descriptive Statistics of the Social Innovation Network**

Indicators	Network with Ashoka	Network without Ashoka
Nb. of links	48082	47052
Av. degree	93.272	91.363
Av. path length	1.909	2.065
Highest distance	2	3
Nb. of components	1	1

Note: The average path length is the average shortest distance between pairs of vertices in the graph.

Source: authors.

Table 3. **The 50 Most Central Actors in the Ashoka Network in France**

Actor	Numbers of links in the network
Third sector – Knowledge Intensive Social Service	
Ashoka	1030
Fondation de France	705
La France s'Engage	418
Fondation MACIF	319
France Active	253
Make Sense	226
Third sector – Large corporation Foundations	
Fondation Vinci	564
Fondation BNP Paribas	352
Fondation Solidarite Societe Generale	282
Fondation Credit Mutuel	281
Fondation Orange	265
Fondation La Poste	232
Fondation Carrefour	228
Fondation Up	270
Third sector – Independent actors	
Fondation Caritas	396
Unis Cite	337
Un rien c'est tout	321
Fondation Abbe Pierre	283
Fondation Croix Rouge Francaise	270
Fondation Perre Bellon	317
Fondation Bettencourt Schueller	281
Third sector – Social Security	
AG2R	300
Malakoff Humanis	230
Public Service – Administration	
Ministry of Education	301
Ministry of Culture	263
Ministry of City	237
ANCT	268
Canope	293
European Union	263
Department of Yvelines	236
Department of North	243
Department Bouches Du Rhone	276
Ile de France	603
Paris	426
Bordeaux Metropole	289
Est ensemble Grand Paris	269
Montreuil	238
Public Service – Funding Agency	
Caisse des Depots	348
Investissements d'Avenir	261
European Social Fund	250
Agence Francaise de Developpement	243
Companies	
Google	331
Latham & Watkins	307
Microdon	293
Recyclivre	269
Capgemini	269
SNCF	251
Simplon Co.	267
Microsoft	233
Hello Asso	260

Source: authors.

institutes.[5] The research output emanating from these centers are then spread among the country's major corporations and therefore, a few public research centers determine the system's technological trajectories (Dosi, 1982). Coordination of the agents is mainly top-down and is initiated by the scientific and industrial policies of the central government. The network provided in this paper can only stand as a partial view of the French NSIS. Nonetheless, it allows one to see that the coordination of actors within the NSIS follows a more bottom-up logic. This claim can be justified in several ways. Firstly, the social innovation projects upon which the network has been built were not initiated by actors from the public sector, nor by large corporations. Secondly, Table 3 lists several mission-oriented public actors: three ministries (Education, City, and Culture), Canopé (a public network promoting reforms in education), and the ANCT (a government agency supporting the local administrations in their projects aimed at improving a territory's economic attractiveness). By nature, these actors are not engaged in providing others with hands-on new technologies to exploit. Besides, ANCT and Canopé put forth a co-production logic and the projects they support are initiated by local actors. In sum, while the NIS is led by the central government, the NSIS, while the former system is led by the central government, the latter one is led by private actors (mostly from the third sector). Apart from the coordination criterion, the NSIS differs in terms of the actors involved. First, there is no research center at the core of the network. Secondly, large corporations are mainly present through their foundations and, except in the case of Vinci (construction industry), these foundations emanate from service industries. Other specific features are, of course, the presence of many third sector agents and that of KISS actors. Interestingly, the funding agencies especially the Caisse des Dépôts and Investissements d'Avenir are major funders of the NIS as well, suggesting the possibility of an intertwining of the NIS and NSIS actors. All in all, despite some common points (especially in terms of funding agencies), the NSIS and the NIS differ in terms of coordination mechanisms and in terms of the actors involved.

Conclusion

The first objective of the paper was to discuss theoretical foundations about the existence of NSIS. Using Baumol's (1993) theory of the allocation of

[5] Such as the National Research Institute for Agriculture, Food and Environment (INRAE), the national institute for research in computer science (INRIA), the Nuclear Energy Commission (CEA) or the National Institute for Medical Research (INSERM).

entrepreneurship among the various types of innovations, we argue that the normalization of social entrepreneurship suggests the existence of a large support system. The second objective was to provide an illustration of a NSIS. With this in mind, we built a large network aimed at producing social innovations in France. In our view, the size and robustness of this network make it a credible picture of the French NSIS. On these grounds, we highlight some marked differences between it and the French NIS. Indeed, the core of the NSIS involves many nonprofit actors and, among them, very few emanate from manufacturing industries. Besides, the coordination of actors seems largely bottom-up, because the social innovation projects at the basis of the system are not resulting from decisions of the central government. One may argue that it is a direct consequence of the methodology that we used for uncovering the NSIS: after all, we started from entrepreneurs and their social innovations. It remains nonetheless the case that the public institutions that proved central in the network are adopting a co-productive stance, instead of providing directions to the rest of the system.

To expand this discussion, the existence of NSIS suggests that many concepts forged into the study of technological innovations (technological regimes, technological trajectories, regional innovation systems, etc.) could be applied to social innovations. This would represent a promising avenue for future research.

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Combining KIBS and Co-Creation Methods for Public Innovation

Fernando Felix
PhD Student, fernando.felix@edu.uah.es

Luis Rubalcaba
Professor, luis.rubalcaba@uah.es

University of Alcalá, Pl. de San Diego, s/n, 28801 Alcalá de Henares, Madrid, Spain

Abstract

The goal of this paper is twofold: i) it provides a framework for the relationship between KIBS and public services, putting the role of service users at the center, and ii) new empirical evidence from a survey for which we test the impact that business services consultancies (KIBS) associated with the co-creation processes have upon the innovation of public services with methodologies such as co-creation (users' participation) and co-design (design laboratories) processes. The empirical evidence focuses upon the two aforementioned core business service methodologies to improve the quality of the public services provision. In this context, we test three main hypotheses regarding whether KIBS have a positive impact upon the innovation of public services and to what extent user-based methodologies are important. Data comes from the 2020 Co-VAL survey on public service innovation for Spain.

The main conclusion is that KIBS have a higher impact upon public service innovation when users are taken into account through co-creation and co-design methods, acting as facilitators for co-innovation and network processes, than when KIBS is just acting on their own in bilateral relationships with the public sector. The overall positive effects do not mean that all uses of KIBS are always positive, for example, some KIBS consultancies subcontracting may have mixed results, but user-focused multiagent frameworks help promote positive impacts.

Keywords: public innovation services; co-creation; co-design; KIBS & ICT consulting; design labs

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Introduction

Following the work of Adebajo (2018), KIBS consultancies, acting as service design consultancies, tend to enable public service improvement by using a user-centric view as a way to facilitate value-in-use through the creation of a new process – or an improvement of old processes – and a new outcome (if that it is allowed by the public administration unit in the contract signed by the KIBS consultancy). Therefore, by quoting Adebajo (2018, p. 575), "…new value propositions are created through the development of new existing practices and resources or through new ways of integrating these practices and resources." This integrative process occurs when the KIBS and ICT consultancies made the value-proposition process they were hired for at the public administration units.

In this paper, we follow that line of thinking that the value proposition that KIBS and ICT consultancies make to public administrations contractors, to improve or create a new way to deliver the services that could have aggregated value for business services and enterprise organizations or have an impact upon services provided to the public. These processes can be ICT, human resources, or input provisions that improve the services delivered by the public administration agencies (Lapuente, Van de Walle, 2020, p. 463).

The research question raised by this work is to test whether KIBS and ICT consultancies have a positive and significant impact on the processes of innovation of public services by making use of the knowledge provided precisely by the main users of government services using what it is called a user-centric point of view. Also, a part of the analysis made in this document is to test different channels of the value-generating processes that KIBS and ICT consultancies have utilized to establish the short-term or long-term impacts of innovations in the public sector reviewed by the Co-VAL 2020 survey, for example, design thinking tools or users' participative involvement in the improvement of processes (Amara et al., 2008, p. 1541). Therefore, the hypothesis to be tested is very close to the work of Desmarchelier et al. (2020, p. 2), who say innovation for established organizations is made in the form of interactions with third-party agents – mainly KIBS – and that these consultancies are specialized in the accumulation and processing of knowledge which they place at the disposal of their clients, who in the Co-VAL survey are public administrative units in Spain. It also alludes to the conclusions made by the Public Governance and Territorial Directorate of the OECD (2017, p. 3) which reports that to meet the innovation challenge governments need to, among other propositions, facilitate the flow of information, data and knowledge across the public sector, and use it to respond creatively to new challenges and opportunities. This is exactly what is tested in this research, how KIBS and ICT companies help improve processes with user participation in the government sector (Gupta et al, 2008, p. 146).

The interaction of the KIBS with the users of the public services is very relevant to the main findings of the paper in the sense that it illustrates the impact that methodology channels and innovative design processes followed by the consultancies have on the improvement of the existing delivery of public services to meet contracts signed with agencies (public administration) (Whicher, Crick, 2019, p. 292). These findings revealed that co-creation and co-design processes are key to improving the delivery of public services by KIBS by reinforcing the methodology used by these consultancies and by being a key value-in-proposition process that the KIBS consultancies provided for the public administration units in the Co-VAL 2020 survey.

Literature Review and Conceptual Framework

In this vein, Zięba and Kończyński (2017, p. 1075) propose that a client co-production process in KIBS could be successful only if the customer anticipates positive changes in the long term, in which the tangible form of this value proposition is newly obtained knowledge and a developed and written strategy. They also show that some of the factors that have a great influence on the co-production process are teamwork, trust, communication, and knowledge flows, all these components are very important in the creation and development of value. In this paper, we take this positive interaction between the customer and the KIBS consultancy provider to search for the creation of a new process or the improvement of the existing public services in order to generate a different and more pro-business kind of public administration (den Hertog et. al., 2010, p. 493).

Misaruca & Viscusi (2015, p. 311) elaborate upon the roles that user participation has on creating public value with two points of views, one internal view referring to how e-government is evaluated with respect to the quality of the services delivered to citizens and a second one regarding the ability to improve the governance system at various levels of implementation (Azad, Faraj, 2008, p. 78). In this paper, the first point of view is selected to find to what extent the KIBS and ICT consultancies improve the quality of the services being delivered to the public in using user-centered methodologies. Also, Criado & Gil-Garcia (2019, p. 445) describe a comprehensive vision of what smart government involves identifying it as a multidimensional phenomenon with diverse elements that are essential for public value generation.

Alves (2012, p. 678) summarizes some of the main postulates of this line of thinking, showing that with the co-creation of value, many of the problems faced by government organizations transform into parts of the solution. This work similarly hypothesizes that raising citizen consent levels and improving the image of the state sector may be attained through the involvement of citizens in resolving problems and developing innovations as they feel that the innovations were created with their involvement and not for them by being part of the solution (Fuglsang, 2018, p. 5).

Similarly, Osborne et al. (2018, p. 23) explain the specific characteristics of co-design and co-innovation as having a locus "…upon the conscious and voluntary involvement of service users in the co-design and improvement of existing public service systems and the co-innovation of new forms of service delivery." They emphasize that most of the service innovations are being derived directly from user involvement in the innovation process, which is particularly the case in this paper.

Finally, Sanders & Stappers (2008, p. 5) explain that the evolution in design research from a user-centered approach to a co-designing role in which there could exist interactive changes in the position of the designer, the researcher and the person formerly known as user. These authors state that those roles are getting mixed-up as explained in recent works and that even if the person who will eventually be served could play a large role in knowledge development, idea generation, and concept development, there is still a need for a formal designer who plays a critical role in giving form to the storm of ideas.

This is where KIBS and ICT consulting comes into the equation as former providers of the structure where co-design ideas come into reality given that users of public services could provide very rich contributions related to value propositions (Chew, 2015, p. 485). Therefore, as Pinto et al. (2019, p. 59) state, consultancies are more critical for the identification of opportunities than in the implementation of innovations, they can even act as project managers. Also, Vinogradov et al (2018, p. 470) explain that single-source procurement of KIBS is an important indicator of procurement efficiency as they are one of the most-efficient methods for achieving high satisfaction and uniquely the most popular for promoting the absorption of services being delivery by those KIBS consultancies. And finally, Lewis et. al. (2017, p. 303) recall that networking creates positive associations with self-rated innovation capacity, innovation drivers, and leadership types of public sector agencies that support innovation.

The main objective of this paper is to test some of the ideas exlored by the theorists of the positive impact that KIBS are having upon the welfare of the European Union's citizens through the use of co-creation and co-design innovation methodologies in the innovative processes of public administration's units of work (Windrum et al., 2016, p. 153; OECD, 2020, p. 19). Some of these spillovers are: i) improvement of the governance system; ii) raising citizen consent levels; iii) improvement of the image of the state sector; iv) procurement efficiency; v) a lift in the self-rated innovation capacity; and vi) the explosion of innovation drivers.

Specifically, the redesign of the role of the government in terms of the increasing public value that KIBS and KIS have on the provision of the public services is tested by exposing the direct and indirect links that these consultancies have on the innovative processes taking place at the public administration's unit of work – in this draft, we focus on Spain specifically (Yuan, 2019, p. 125).

Definition and Scope of Public Innovation

One way public innovation can take place is through the improvement of the government services it provides to its citizens or to enterprise organizations, which is reflected by the reduction of time spent at the units of work of public services, by the less time-value wasted doing a necessary process to pursue the implementation of a right for a citizen or entrepreneurial organization – which in fact is a service that an institution is providing its members. It can also simply be an improvement in the way the government service is provided making the public have a feeling that the government makes an effort to provide better and – in some cases – sustainable services, which overall generates a good evaluation of the public administration that is trying to make the processes work much better and less costly for its citizens (a feeling that taxes are working for the good of the people) (Sangiorgi, 2015, p. 334).

This is the way that Rubalcaba et al (2011, p. 21) describe the identification of public sector organizations as they are institutions that react to user needs and preferences through the day-to-day interaction with citizens at the service level, bottom-up. They also have a top-down initiatives and are considered production units where processes may vary from regulation and resource allocation to service and welfare.

The Observatory of Pubilc Sector Innovation (OPSI) (OECD, 2017, p. 3) says that in order for governments to foster public innovation, some general activities are recommended such as i) addressing the investment in public servants as those who are the catalysts of innovations; ii) facilitating the flow of information, data, and knowledge across the public sector; iii) promoting new organizational structures to improve approaches and tools; and iv) ensuring that internal rules and processes balance their capacity to mitigate risks.

The OPSI synthesizes five main categories of innovation organization activities such as the support and coordination of innovative solutions, experimentation, supporting service delivery, investment and funding of public projects, and networking support (OECD, 2017, 146). This same observatory describes many tools that can push public innovation forward, among those are co-creation and lab design tools, which are the main positive contributors to the impacts analyzed in this paper.

The OPSI explains that co-creation through co-production and co-delivery can assist innovation teams in implementing projects that meet users' needs and make them feel a part of the result, therefore engaging many users in creating these solutions, which helps create ownership and ensures better results and, therefore, higher tolerance for potential failures. Also, the OPSI states that innovation labs and units can overcome some of the barriers to public sector innovation, providing space to develop new ways of doing things (OECD, 2018, pp. 52-53).

Reinforcing this approach, in a multi-agent framework, Windrum et al (2016, p. 162) find that co-creation of novel services on social innovations is guided by the prominent position that citizens, social entrepreneurs, or third sector organizations (NGOs or charities) take in the innovation processes, therefore shaping the inter-linkages between service and social innovations.

The role of this paper is to test those ideas using the general linear modeling framework based on probit regressions and path analysis – structural equation modeling (SEM). These regressions are set to test the direct and indirect causality that KIBS and ICT covariates – and co-creation and co-design variables – are having on public service innovation processes. Probit regressions and the like were defined to estimate binomial distributions as the main dependent variables tend to behave like those functions (as the general statistics describe that patterns) and the use of the maximum likelihood estimation results in consistent, asymptotic to normality, and, in some cases, efficient coefficients, which were the main estimations of the paper.

In order to test the hypothesis of the impact of KIBS on the innovation of public services in this paper, we follow the work of Adebajo (2018) and Zięba & Kończyński (2017), who proposed that KIBS consultancies in public services may take a user-centric view of how innovation affects the user in terms of facilitating value-in-use through the creation of a new process (or an improvement of an old process), which is called co-creation, and that co-design fosters reciprocal learning among the participating actors and potentially positions the service design consultant as an important catalyst for value creation in the public sector.

In this line of thinking, KIBS and ICT consultancies mainly help administrative units that provide public services in a two-fold way. KIBS and ICT services first act directly as consultancy providers in public services related to business or enterprise communities, and second, they interact with user methodologies in the innovation processes, providing their know-how and technology to the administrative unit and helping them improve the innovative process as design laboratories.

In the following graph (Figure 1), these two-fold processes can be seen.

Both interactions are reinforced by users' participation (co-creation) and users' contributions (co-design) in the innovation processes of the KIBS and ICT consulting services to improve the public services. These co-participation processes contribute strongly to the innovative hub developed by administrations to pursue a better provision of public service (Yu, Sangiorgi, 2017, p. 82). Therefore, these innovations show that public innovation strongly cooperates with KIBS or ICT services that heavily rely on users' interactive participation (Schmidthuber et al. 2019, p. 345).

Descriptive Statistics of Co-VAL's Database and the Reasoning behind the Estimated Methods

Description of Co-VAL's Survey and the Database Used in This Paper

In 2020, the European Union (the H2020 EU project, Co-VAL) conducted a new survey related to the main channels of innovation processes in the public sector driven by KIBS and users' intense methodologies. The unity of work was defined as the main area under the responsibility of the respondent which included all employees under one's direct supervision. The unit of organization was defined as the government entity that hired the public manager and it could be an agency, ministry, or a public department inside the municipal, regional, or national government or even a think-tank working for different levels of government.

Specific questions of Co-VAL Survey included the main characteristics of the unique administrative offices, the principal users of the new or improved public sector services or processes, and the significant characteristics of the innovation processes driven by KIBS with the help of users' intense participation like co-creation and design laboratories.

Innovation is defined as a new or improved service or a process that differs significantly from previous ones implemented at the respondent's unit of work. Also, some specifications were made as innovation has to be: i) new or substantially improved only at the respondent's unit of work; ii) it could be partially or fully implemented; and iii) it could have multiple characteristics – a new service could be combined with improved processes for service delivery.

The KIBS sectors identified from this survey are:

- management, scientific, and technical consultants (NACE 70.22 & 72.20);
- computer systems design and related services (NACE 62.01, 62.02 & 62.09);
- other professional KIBS which include legal services (NACE 69.10) and accounting (NACE 69.20); and,
- other creative KIBS which include specialized design services (NACE 74.10 & 74.90) and advertising, public relations, and related services (NACE 73.11, 73.12 & 73.20).

As the Co-VAL survey (2021, p. 3) explains, the main H2020 Co-VAL survey was conducted as a statistically representative example from 1,036 public sector managers in six countries (Spain, France, Hungary, Netherlands, Norway, and United Kingdom).[1] In Spain, the response rate was 37.7%. In this country, which is the principal objective of this paper, 79.5% of 264 work units in this survey expressed themselves as innovators, which is a lower percentage than expressed by similar units in the Netherlands, Norway, or the United Kingdom (around 90%). Some key findings are that around 87% of the managers, surveyed in those six countries declared that the involvement of users in the development of a "*most important innovation*" is very common. Also, 14.5% of those managers reported obtaining assistance for a most important innovation from organizations such as design firms, innovation labs or living labs that often involve users in developing innovation. Although this is a small part of the managers that report having user involvement in innovation activities, in this paper, we have found evidence, at least for Spain, that those processes are significant for innovative public administration units delivering a service to an enterprise organization or directly to business.

The Variables, the Hypothesis, and the Model

From the survey we decided to gather business service-related variables in order to test whether there is a direct and positive relationship between KIBS consulting and the improvement of public services. We also extracted variables related to core business service methodologies like co-design and co-creation as specific ways to improve the quality of the public services' provision. All these variables were utilized with ones that expose public services innovation.

The variables of the survey that are related to KIBS are: i) C7ag (innovations that come from businesses, including consultants); ii) C11d (assistance from businesses, including consultants); iii) C11e (design firms or innovation laboratories); and iv) C11f (assistance from providers of specialized software or ICT equipment). The variables that represent users' active participation and design innovation methodologies are a) C12 (methods used to develop innovations); b) C13 (methods used to obtain inputs from users); c) C15 (effects of involving users on outcomes); and d) C16 (innovation effects).

Finally, the three variables describing the innovation of public services are: 1) B1d (innovation of public services for business or enterprise association users); 2) B1e (innovation made in support activities for the organization – ICT, maintenance, shopping, accountability, human resources, etc.); and 3) B1f (innovation of public production processes or services).

Descriptive Statistics

Next, the main statistics of the variables referred to in the previous section are shown (Table 1).

Most variables have large standard deviations meaning that the confidence levels have to be wide. Only two of the assessed variables have a complete record in the database, the rest have a high proportion (30% or more) of the data not available. Therefore, the degrees of freedom for them diminish at a rapid rate. The variable related to the KIBS (C7ag) consultancy has a high kurtosis coefficient and high skewness coefficient with both indicators translating into having a spike around a point in the data (zero) and by being skewed to the left which is an indicator of a binomial distribution with a high proportion of zeros. The variable related to public innovations for business services (Pinn2B) also has the same pattern for binomial distribution as that described for the KIBS variable but with a lesser kurtosis coefficient.

The variables that describe the innovation processes related to KIBS and ICT consultancies and design laboratories innovation (C11d, C11e and C11f) behave like binomial distributions.

The variables related to the business service methodologies, from C12 to C16 and co-creation (users' participation) described in Table 1 are diverse in their distributions. Among those are met``````hodologies for identifying and developing user contributions and a variable that reflects

[1] https://www.co-val.eu/public-deliverables/, accessed 16.09.2021.

the users' contributions to the innovation processes – C12 and C15 – which have a normal distribution. There is a variable that defines the co-creation process – C13 – which has a normal distribution and a variable that has a negative binomial distribution (C16).

For example, two of the main variables that are part of the analysis like the one describing the public innovation to business process - Pinn2B (B1d) - and the business service consultancies variable - KIBS (C7ag) – are closer to binomial-like distributions and not to normal-like distributions (See Table 1). Those characteristics of the binomial distributions are also shown in the variables related to the innovation made by methodologies used by KIBS consultancies - B2PInn (C11d), design laboratories - dInnLabs (C11e), and by ICT and hardware consultancies - ICT (C11f).

It was also revealed by the general statistics that the same kind of distribution applies to the variables that express the innovations in support activities related to the unit of work such as ICT, maintenance, buying, accountability, and human resources (B1e) or for processes related to production or service deliveries (B1f).

Also, it can be seen from the covariance matrix (Table 2) that, in the first equation, the three variables that have the most influence on the innovation in public services related to business or enterprise organization variable (B1d), those related to KIBS consulting (C7ag), and KIBS-centered methodologies (C11d), and those reflecting innovation effects (C16). This is what it happens to the second and third equations in which ICT and KIBS consulting processes, with the support of design laboratories and co-creation activities, have a positive influence on the innovation of public services variables in which the general improvement in production processes or service delivery - PprodServ (B1f) – is reflected or the service support activities - PInnSuppA (B1e) – is analyzed.

With similar tables, it can be shown that support activities related to the unit of work (ICT, maintenance, buying, accountability, human resources) – QB1e – which are classified as KIS or KIBS consultancies are most influenced by design innovative laboratories (C11e), ICT software consulting or hardware provision (C11f), and co-creation methodologies (C13). And finally, with the same analysis of the covariance matrix, it can be said that the variables having the most influence in the processes related to the production or service deliveries (B1f) are KIBS methodologies, design innovative laboratories (C11e) and business-like innovative methodologies (C12).

From all these relationships it can concluded that different levels of integration tend to occur among these variables.

So, to prove these hypotheses, we first test the following three equations:

$$Y1 = a1 + b1*X1; \quad (1)$$

$$Y2 = a2 + b2*X2; \quad (2)$$

$$Y3 = a3 + b3*X3. \quad (3)$$

Where Y1, Y2, and Y3 represent the public innovation's dependent variables and X1, X2, and X3 are the KIBS independent variables.

Then the interaction of KIBS and user-centered methodologies is tested as these processes tend to be the main sources of value-added at their consultancies, by the following three equations which are slightly more complicated than the ones expressed before:

$$Y1 = a1 + b1*X1 + c1* Z1; \quad (1A)$$

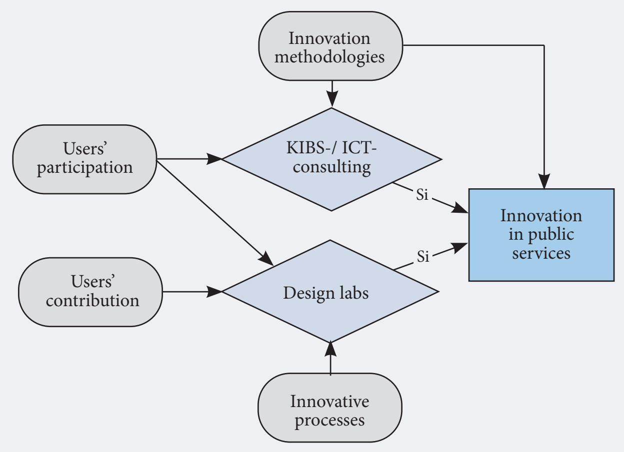
$$Y2 = a2 + b2*X2 + c2*Z2; \quad (2A)$$

$$Y3 = a3 + b3*X3 + c3*Z3. \quad (3A)$$

Where Y1, Y2, and Y3 represent the public innovation's dependent variables, X1, X2, and X3 are the KIBS independent variables and Z1, Z2, and Z3 are the variables having the user-centered interaction with KIBS and public service innovation.

The interaction between KIBS and public services' innovation is not linear, as will be proven in the next section of the paper but, in contrast, it has

Figure 1. **Two-Fold Processes of the Improvement of Public Services by KIBS and Design Laboratories**



Source: authors.

non-linearities which can be seen in the next diagram where we can see that the Z's variables have a direct relationship with the public innovation variables and also have a linear impact on KIBS and, therefore, an indirect impact on public services' innovation.

These non-linearities can be seen in the following diagrams that explain the indirect effects of the user-centered methodologies.

Logit, Probit, and SEM Models

The Co-Val survey was held to gather data in order to understand the drivers of innovation in public services and the database was gathered using binary answers to indicate positive or no innovation processes being held by the public administration unit. Therefore, logit or probit models for explaining the interaction of the covariates that determine whether the improvement processes are a good way to explain the interaction described by previous paragraphs.

Logit estimations are mostly used in econometric tests to model the probabilities that the response belongs to the reference class (in this case, a positive innovation process) by applying the logistic transformation to a proposed equation of our dichotomous dependent variable model to insert non-linearities during the estimation process and to narrow the probability range to a 0 or 1 decision – as in the Co-Val survey. From that point of view, we used a maximum likelihood algorithm to estimate the logistic regression parameters to find the probability of belonging to a reference group – the innovative one. After calculating the logarithm of the odds for the proposed estimated equation, we can express the right estimated equation among the co-variates – which are now linear - and the dependent variable (Davidson, 2018).

Table 1. **Descriptive Statistics of the Main Variables**

Variable	mean	std	cv	skewness	kurtosis	n	n.a.
PInn2B (B1d)	0.137	0.34	2.51	2.114	2.47	1109	0
PInnSuppA (B1e)	0.330	0.47	1.40	0.740	1.50	1109	0
PprodServ (B1f)	0.220	0.42	1.90	1.300	2.80	1109	0
KIBS (C7ag)	0.039	0.19	4.98	4.785	20.93	1109	0
B2PInn (C11d)	0.177	0.38	2.16	1.696	0.88	627	482
dInnLabs (C11e)	0.341	0.47	1.39	0.672	–1.55	645	464
ICT (C11f)	0.631	0.48	0.77	–0.544	–1.71	710	399
m2Pinn (C12)	4.158	2.26	0.54	–0.06	–0.84	785	324
m2CoCrea (C13)	1.818	1.54	0.85	0.485	–0.72	736	373
CoCreaEff (C15)	12.599	5.41	0.43	–0.089	–0.55	613	496
InnEff (C16)	27.227	8.42	0.31	–0.97	0.39	789	320

Source: based on data by H2020 EU project, Co-VAL.

Alongside the logistic regression models are the probit regression estimations which assume that the distribution of the errors behaves like a normal one. In this paper, we assume the proposition that the cumulative distribution function is standard normal, being a consequence of the statistics of the main data variables. Also, the econometric results of the logit and the probit models for the data are very similar and the main advantage of this Gaussian normal distribution model is that it directly generates the marginal effects of the covariates on the dependent variable. Therefore, the probit estimation models were used to generate the marginal effects of the covariates over the innovation process binary response variable, with similar results to those obtained for logit regression models being held simultaneously and being illustrated in the summary results table.

Following Hanck et al. (2020), we assume that the expectation of the dependent variable based on the co-variates is described by the following equation:

$$E(Y|X)=P(Y=1|X)=\Phi(\beta 0+\beta 1X),$$

where $\beta 0+\beta 1X$ plays the role of a quantile z and that $\Phi(z)=P(Z\leq z)$, and where $Z\sim N(0,1)$ behaves as a Gaussian normal distribution, such that the probit coefficient $\beta 1$ is the change in z associated with a one-unit change in X (i.e. a marginal effect in economics). Although the effect on z of a change in X is linear, the link between z and the dependent variable Y is non-linear since Φ is a non-linear function of X.

Besides obtaining the marginal effects from the probit and logit models, we tested a simultaneous equation model approach to try to delineate the main processes that push innovation forward at public administration units. It seems that various processes are bound together, not always the same ones gather together in an obvious way, to generate good practices for innovative processes being held at public services. So, we tested those hypotheses with the structural equation model instruments using path analysis.

Structural equation models (SEM) were used to try to delineate the various interactions among the

Table 2. **Covariance Matrix of the Main Variables**

Variable	PInn2B (B1d)	KIBS (C7ag)	B2PInn (C11d)	dInnLabs (C11e)	ICT (C11f)	m2PInn (C12)	m2CoCrea (C13)	CoCreaEff (C15)	InnEff (C16)
PInn2B (B1d)	**0.1184**	**0.0100**	**0.0200**	0.0053	0.0093	0.0803	0.0285	−0.0331	**0.3079**
KIBS (C7ag)		**0.0373**	**0.0181**	**0.0130**	0.0069	**0.0668**	**0.0444**	0.0243	0.0514
B2PInn (C11d)			**0.1459**	0.0018	**0.0232**	**0.1627**	**0.0823**	−0.3332	**0.2749**
dInnLabs (C11e)				**0.2251**	**0.0479**	**0.1958**	**0.0864**	**0.6130**	0.3060
ICT (C11f)					**0.2332**	0.2472	**0.1305**	**0.4241**	0.0889
m2PInn (C12)						**5.1000**	**1.5700**	**4.3181**	**3.3074**
m2CoCrea (C13)							**2.3641**	**2.3390**	**1.7439**
CoCreaEff (C15)								**29.2374**	**12.6696**
InnEff (C16)									**70.9370**

Source: based on data by H2020 EU project, Co-VAL.

variables that generate the innovative processes at the public administration units described in the Co-VAL survey, reflecting the consulting procedures that expose the results of the innovation procedures without imposing a specific distributional assumption on the data. SEM models use partial least squares (PLS) estimations to provide causal explanations of the related variables for which there are not *a priori* established relationships among them, and these estimations are based on the theorized relationships that were the previously illustrated by the probit and logit models. In that way, the use of SEM models, by using them with path analysis structure, is like a two-step regression model in practice or simultaneous equation models used in two-step general least squares' estimations.

Path analysis is a subset of structural equation models and is also called the analysis of covariance structures, where exogenous variables are, generally, correlated between them and have direct or indirect effects, through another exogenous variable, to the dependent variable. In this paper, the exogenous variables related to co-creation and lab design processes indirectly affect the dependent variable which becomes the innovation process being carried out by the public administration unit.

Path analysis is based on a closed system of nested relationships among variables that are represented statistically by a series of structured linear regression equations.[2] Therefore, to do path analysis is to test simultaneously equations models and it becomes the responsibility of the researcher to give it the proper structure to be tested so that it makes economic sense.

To utilize SEM models with path analysis, we first gather the results obtained in the probit and logit models choosing the co-variates with high covariance with the dependent variables to be estimated in a first step estimation procedure, and in the second-step estimation procedure, we load the path analysis in the SEM software (lavaan for R statistical package), with the appropriate equations obtained in the previous regression stage. The results are illustrated in the following diagrams of the next section of this paper.

Main Econometric Findings

The interaction between KIBS-centered methodologies and KIBS consulting for the improvement of public services used by business or enterprise associations is calculated using equation (1A) (Figure 2).[3]

$$PInn2B = a1 + b11*KIBS + b12*B2PInn + c11*m2PInn + c12*m2CoCrea + c13*InnEff \quad (1A)$$

Interaction between user-centered methodologies and co-design and ICT consulting for the improvement of support activities of the unit of work or organization (ICT, maintenance, buying, accountability, human resources, etc.) is calculated using equation (2A) (Figure 3).[4]

$$PInnSuppA = a2 + b21*dInnLabs + b22*ICT + c21*m2PInn + c22*CoCreaEff + c23*InnEff \quad (2A)$$

The interaction between KIBS and co-design methodologies and KIBS consulting for the improvement of production processes or public services delivery is calculated using equation (3A) (Figure 4).[5]

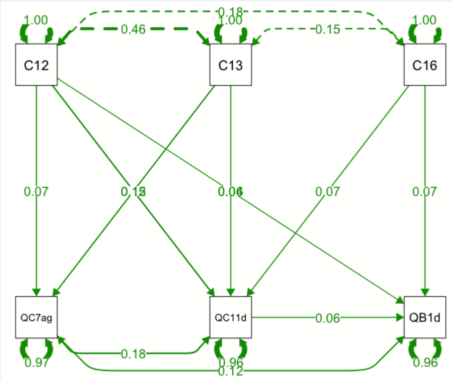
2 https://www.publichealth.columbia.edu/research/population-health-methods/path-analysis#readings, accessed 14.08.2021.

3 These covariances among users' co-creation and KIBS impact on public services innovation are well described in the work of Adebajo (2018).

4 Following Sanders & Stappers (2008) on the impact that design laboratories have on public services innovation's performance.

5 Taking the involvement of users of public services, like Osborne et. al. (2018) describe in the process of co-innovation of new forms of service delivery.

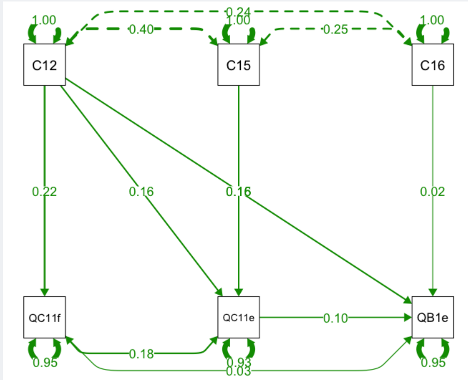
Figure 2. **Diagram of Equation 1A**



Inputs:
C12 = methods used to develop innovations (m2Pinn)
C13 = methods used to obtain inputs from users (m2CoCrea)
C16 =innovations effects (InnEff)
C7ag = innovations that came from businesses, include consultants (KIBS)
C11d = assistance of business, include consultants (B2PInn)
Output:
B1d = innovation of public services for business or enterprise associations users (PInn2B)

Source: based on database of H2020 EU project, Co-VAL with path regression analysis.

Figure 3. **Diagram of Equation 2A**



Inputs:
C12 = methods used to develop innovations (m2Pinn)
C15 = effects of involving users on outcomes (CoCreaEff)
C16 = innovations effects (InnEff)
C11e = design firms or innovation laboratories (dInnLabs)
C11f = assistance of providers of specialized software or ICT equipment (ICT)
Output:
B1e = innovation made in support activities for the organization – ICT, maintenance, shopping, accountability, human resources, etc. - (PInnSuppA)

Source: based on database of H2020 EU project, Co-VAL with path regression analysis.

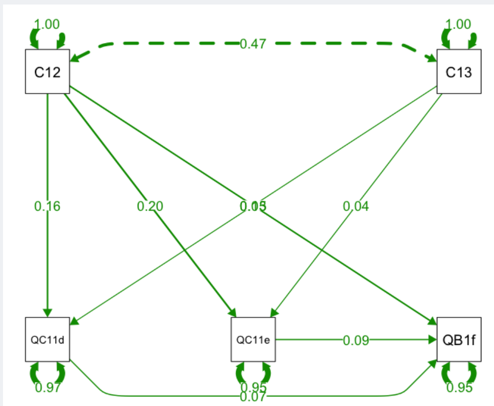
PprodServ = a3 + b31*B2Pinn + b32*dInnLabs + c31*m2Pinn + c32*m2CoCrea (3A)

Results of the Multivariate Analyses

Once the main correlates of the dependent variables were expressed, the binomial distributions were approximated using logit estimators and the results can be seen in the following table.

From Table 3, the impact of KIBS, ICT, and design laboratories have on public innovation services is tested in a two-fold manner. First, traditional KIBS and ICT consultancy variables have a positive and significant impact on the innovative processes to improve public services, especially those that are related to business services or pro-enterprise organizations and provide support activities for the public administration unit or for the production or processing of public services. All the public services asked to be subject to innovative processes have a positive impact on the KIBS and co-design consultancies due to their improvement. Second, the integration of co-creation, co-design, and business-like improvement methodologies in the analysis only improves the positive and significant impact of the KIBS consultancies on the public services processes. Therefore, having a positive

Figure 4. **Diagram of Equation 3A**



Inputs:
C12 = methods used to develop innovations (m2Pinn)
C13 = methods used to obtain inputs from users (m2CoCrea)
C11d = assistance of business, include consultants (B2PInn)
C11e = design firms or innovation laboratories (dInnLabs)
Output:
B1f = innovation of public production processes or services (PprodServ)

Source: based on database of H2020 EU project, Co-VAL with path regression analysis.

and impulse-like covariate function on KIBS and ICT services and, consequently, a positive impact, channeled through the KIBS and ICT services is a consequence of the improvement of the processes of the public administration units in the Co-VAL survey.

In this economic way, it can be concluded that a dynamic way of the integration path of KIBS and ICT consultancies with co-creation and design laboratories methodologies results in a positive and significant improvement of the innovation processes of public services, which the 2020 Co-VAL survey on public service innovation was designed to extract in Spain in 2020.

Discussion

In this paper, the kind of interaction that business services methodologies have on public services innovation has been illustrated. The role of service users at the center of the innovative process was tested as the impact that knowledge-intensive business services consultancies (KIBS) associated with co-creation processes have on the innovation of public services with the main help of methodologies like co-creation (users' participation) and co-design (design laboratories) processes.

The model builds on the work of Adebajo (2018) and Zięba, M. & Kończyński, P. (2017), as both authors recall the importance of the interaction among the customer (in this case the public administration or unit of work) and the KIBS consultancy provider inside the innovative process as a way of creating a new service or improving the public administration services delivered to business services, enterprise organizations or just to lease the internal adjustment regarding the provision of those processes. These two ways of innovating in the provision of public services also relied on making more efficient use of software, hardware, human resources, or other key resources at the unit of work, in this case, the public administrative offices.

In this context, we tested three main hypotheses regarding whether KIBS have a positive impact on the innovation of public services and to what extent user-based methodologies are important. All three hypotheses had a positive and significant indirect effect on the co-design and co-creation methodologies of the KIBS consultancies and, therefore, over on quality improvement of public sector innovative processes.

As these effects proved positive and significant for both types of regressions, the probit and SEM – path – analysis, tested in this paper, the main policy for public innovation is to reinforce and upgrade the quality of these consultancies to generate more and increase value-added in the public sector provision of services.

Yet the empirical estimation procedures used throughout this paper have inherent limitations. First, the logit and probit tests are relying on the assumptions of a Gaussian normal distribution - probit - and on the independent distributions of

Table 3. **Main Econometric Findings with Probit Regressions**

	Dependent variable					
GLM	PInn2B		PInnSuppA		PprodServ	
Regressors	Eq. 1	Eq. 1A	Eq. 2	Eq. 2A	Eq. 3	Eq. 3A
KIBS	0.877*** (4.39)	1.85 *** (2.54)				
B2PInn		1.35 ** (2.02)			0.2416 (1.80)	1.27 (1.56)
dInnLabs				1.24 * (1.89)		1.28 ** (2.03)
ICT			0.2251* (2.29)	1.21 * (1.69)		
m2PInn		1.04 (0.72)		1.15 ** (2.26)		1.26 *** (3.98)
m2CoCrea				1.08 (1.29)		
CoCreaEff.						
InnEff		1.11 * (1.74)				
Constant	–1.142*** (–23.30)	0.40 *** (–13.97)	–0.2811*** (–3.58)	0.71 *** (–3.80)	–0.5513*** (–9.45)	0.55 *** (–8.50)
Obs.	1107	612	708	583	625	583
X^2		19.41 ***		26.74 ***		30.21 ***
Pseudo R^2 (Cragg-Uhler)		0.05		0.06		0.07
BIC		635.02		805.12		723.82
Log-likelihood	–434 on 1107 d.f.		–485 on 708 d.f.		–385 on 625 d.f.	
Degrees of freedom	868		708		625	

Source: based on data produced by H2020 EU project, Co-VAL with path regression analysis..

the error terms - for both estimations, which we supposed were based on the statistical qualities of the database. This distribution supposition can be improved with more tests over distribution characteristics. Also, the premise of the identical and independent distribution of the errors could prove flawed as we estimated simultaneous equations that had covariation among two or three variables, therefore making this kind of procedure more realistic than estimating separable probit or logit equations. In the end, the estimations using simultaneous – by using path analysis – equations modeling proved superior (to the single dichotomous models), as having more realistic coefficients (with better t-statistics) and having captured the channels of indirect effects of the processes that help KIBS and ICT consultancies improve innovative processes of public units of work.

Conclusions

The two main core business service methodologies of co-design and co-creation were tested as specific ways to improve the quality of the public service provision. In both cases of the users at the center of the methodologies, the results explicitly tell us that there is a positive indirect effect by the KIBS and ICT consultancies on the improvement of public services provision. Therefore, users at the center of these methodologies are shown to have a reinforcement effect on the KIBS and ICT services and on public service innovation, which is complementary to the direct effect that KIBS have on public innovation services.

The main conclusion is that KIBS have a higher impact on public service innovation when users are considered through co-creation and co-design methods, acting as facilitators for co-innovation and networking processes, than when KIBS are just acting on their own in bilateral relationships with the public sector. The overall positive effects do not mean that all use of KIBS is always positive, as far as some individual KIBS consultancies subcontracting may have mixed results, but user-centered multiagent frameworks help promote positive impacts.

Therefore, one of the main conclusions of this paper is that public innovation processes could be redirected toward more insight-based consultancies in the improvement of the services being analyzed to public results testing – with the internal gathering of information as co-creation and lab design proved to have a positive impact on the innovative process. These methods are the ones that help citizens and enterprise organizations to generate private value (Skålén et al., 2015, p. 139). As a secondary outcome, the contracting of KIBS and ICT consultancies *per se* does not necessarily generate a positive innovative process and that even having that counted as innovative for the public administration unit does not necessarily produce an increase in public value. If cocreation is not managed in the right way, value destruction may even happen. So, the main policy advice for public managers is that the innovative processes of public units can benefit from an integrated co-creation approach to innovation as far this is directed toward a public goal, aligning public and private aims, that generates public value.

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Obstacles to Digital Innovation in KIBS — The Case of Law Firms in Poland

Krzysztof Durczak
PhD Student, krzysztof.durczak@ue.poznan.pl

Marek Gnusowski
Assistant Professor, marek.gnusowski@ue.poznan.pl

Maciej Ławrynowicz
Professor, m.lawrynowicz@ue.poznan.pl

Poznań University of Economics and Business, Al. Niepodległości 10, 61-875 Poznań, Poland

Abstract

As digitalization continues to fundamentally change professional work, we examine obstacles to technological innovation in the legal sector, which is a notable outlier when compared to other knowledge-intensive business services (KIBS). This paper aims to explain the lower engagement with technological novelty in legal services in contrast to other KIBS spearheading global innovation.

We adopted a mixed-method approach, combining both deductive and inductive inferential modes in a pragmatic manner. We used a quantitative analysis of law firms (n = 258) to establish baseline observations that were used to understand the attitudes toward the use of technology in addition to interviews with individual lawyers (n = 28).

The study broadens the understanding of obstacles to digital change in small law firms operating on the periphery of the global market. Six different barriers clustered in two groups were identified: three reflect the character of individual work, two are related to law firm performance, and the last reveals an overarching problem in technology design. The discussion extends the debate on technological disruption in legal services.

The reluctance to adopt digital innovations is not irrational when the drawbacks of creative disruption are considered. Endogenous change would require altering fragmented structures of local markets for companies to grow via an economy of scale. It is more likely that digital novelties will continue to develop from the global market delimited by the English language.

A better understanding of obstacles to technological innovation may serve lawyers, managers, and LegalTech providers with material concerns that need to be addressed.

eywords: KIBS; digital transformation; lawyers; law firms; legal services; professional services

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Introduction

When the first seminal report (Miles et al., 1995) on Knowledge-Intensive Business Services (KIBS) emerged, scholarly interest in the subject gradually uncovered the importance of these companies for the economy. By providing, exchanging, and transferring expert knowledge to address the needs and concerns of other businesses, KIBS are becoming the backbone of modern economies (Miles, 2005). They are also a significant factor in the diffusion of novel ideas (Miles et al., 2019) by facilitating organizational change (Santos-Vijande et al., 2012), as well as translating novel solutions within and between industries (Hertog, 2000).

Innovation, in the Schumpeterian spirit (Schumpeter, 1942), is commonly considered a causal factor of social and economic progress (Aghion, Howitt, 1992). Given the significant role of KIBS in pushing future horizons at the systemic level (Sundbo, Gallouj, 1998), it becomes increasingly important to understand the reverse perspective of how these companies engage with innovation by providing new or better services at a lower cost to create value for their clients. Although not frequently researched, several studies have already stressed the importance of these reversed optics (Braga, Marques, 2016; J-Figueiredo et al., 2017).

KIBS are generally considered intrinsically innovative for their own benefit (Toivonen, 2004) due to the pace of technological change, competitive pressure, and clients' expectations. Accordingly, Gotsch et al. (2011), using Community Innovation Survey (CIS) data for EU27 from 2004, found that KIBS tend to portray themselves as innovative companies, reporting that the average share of innovative companies was 33% higher for KIBS than the market economy and 24% higher than the manufacturing sector. As noted by other researchers (Miles et al., 2019), however, this sample did not include legal, accounting or advertising services. When a similar study was conducted by Hipp et al. (2015), rates of innovative firms between KIBS and manufacturing were roughly similar. This is understandable because the groups of KIBS that were omitted in the first study generally report lower levels of innovation. Therefore, including them in the latter study likely balanced the scales.

The divergence between the results of those studies points to an inner variance of innovation among KIBS, which constitute a very heterogeneous cluster of firms that vary in size, operation, scale, and services. As a result, not all KIBS are equally cutting-edge. First, small service firms engage less deliberately in innovation boosting activities, such as strategic attention, planning of renewal activities, market research, and employee involvement (Vermeulen et al., 2005). Second, KIBS tend to be geographically "sticky" (Miles, 2005) and as their clients rely on their local knowledge, the motivation to innovate might be limited. Third, larger companies may develop bureaucratic rigidity as they scale, but they also gain resources (e.g., finance and manpower) that extend their innovative capacity, especially when compared to the limitations of innovation experienced by small firms (Bumberová, Milichovský, 2020).

Novelty, however, also comes in different forms. Hipp et al. (2015) report significant differences among KIBS regarding the type of innovation they dominantly pursue. CIS data, which is used in their study, is constructed based on the Oslo Manual, which defines innovation as "a significant degree of novelty for the firm" (OECD, 2018, p. 8) and divided into four categories (Table 1). These four types of innovation often are classified as either technological or non-technological forms of novelty, as ordered in the table below (Amara et al., 2016; Chichkanov et al., 2019).

In this context, Hipp et al. (2015) found that up to 77.7% of Research and Development (R&D) services reported introducing some kind of technological innovation, whereas this rate exceeded 50% for most other KIBS. Human Resources (HR) and consultancy services (legal, accounting, audit, management, and market research) however reported only about 20%. This variation is logical because innovation is often considered a low priority by professional service firms (Brooks et al., 2018; LexisNexis, 2014), leading to resistant attitudes toward new technologies that change traditional practices of work and business (Ribstein, 2010).

Innovation in Legal Services

Among KIBS that involve professional expertise (P-KIBS), however, there is one group that has particularly limited engagement with novelty. In two studies regarding the scale of innovation among KIBS in the United Kingdom (Miles, 2005) and Germany (Schmidt, Rammer, 2007), the clustered group of legal and accounting services scored the lowest positions. They also preferred introducing non-technological forms of novelty at their companies. This observable aversion toward technology makes this group an interesting case of outliers in the context of all other KIBS.

In this study, we focus exclusively on legal services, which we consider to be a cluster of KIBS (Eurostat, 2008; Miles et al., 1995) that lacks innovative practices. Lawyers are often seen as bystanders to change, relying on proven practices (Windrum, Tomlinson, 1999). On the one hand, this is understandable given that professional services (P-KIBS) primarily provide non-routine services, which because of their reliance on intensive-knowledge work and problem-solving, are less likely to be intensive users of new technology (Miles et al., 1995). However, there might also be a cultural factor at play, as maintaining the law's stability and predictability is part of a lawyer's responsibility, which may explain why lawyers have historically been slow to embrace change (Felstiner, 2005). Although lawyers have become increasingly aware of keeping up with technological progress (Gnusowski, 2017), the legal industry still remains resistant to the creative destruction that is experienced across many other sectors (Chishti et al., 2020, p. 15).

Simultaneously, this reluctance cannot be easily explained by a lack of available digital solutions, as the efforts to enhance legal work has been happening for some time now. This is especially true in terms of progressing digitalization, which is understood as the use of information technologies to create value for a company (Sommarberg, Mäkinen, 2019). Automating and optimizing processes may spur productivity boosts, cost savings, streamlined service delivery, a reduction of human error, and a culture of innovation (Parida et al., 2019; Scott et al., 2019). In the legal sector, this belief has already spawned many digital technologies meant to facilitate daily work, management, and delivery of services. Given the scarcity of comparative sources on what is often referred to as LegalTech, we composed a table based on Chishti et al. (2020) to review areas addressed by digital technologies.

LegalTech companies (Chishti et al., 2020) apply technological advancements to facilitate the practice of law both internally — by replacing routine tasks and supporting professional work with computer-assisted aids — and externally — by creating new opportunities stemming from this progress (e.g., legal liability of actions performed by artificial intelligence). They also aim to help consumers gain access to legal expertise through organized information systems and interfaces (e.g., chatbots). Chishti et al. (2020) argue that a worldwide trend of intensive regulation increases the general demand for legal awareness and expertise, pressuring law firms to deliver their services more efficiently, i.e., at lower cost and in a shorter amount of time.

Therefore, these companies are presumably becoming increasingly digital, prompted by technological advancements to identify new ways of creating, delivering, and capturing value from their activities (Brooks et al., 2020). On this basis, some researchers claim that the legal field is at the advent of a revolution in the assessment, acquisition, processing, and delivery of legal knowledge (Susskind, Susskind, 2015). This reality could explain the general reluctance of lawyers to embrace digital technologies, if it were not for the current employment and compensation trends or the relational and creative problem-solving character of legal work (Miles et al., 2019) that paint these predictions at least a tad overdramatic.

In addition, Brooks et al. (2020) point to confusion in the literature between simple work automation and the advanced functions performed by artificial intelligence (AI). Whereas the former gains relative popularity by removing or replacing routine chores, the latter is still quite far from being able to replace higher cognitive functions exercised by humans, especially professionals. AI solutions based on machine-learning in the legal sector are focused on augmentation rather than automation (see (Davenport, Kirby, 2016; Raisch, Krakowski, 2021) for the discussion of the difference), and therefore, lawyers should presumably be more likely to employ these technologies in their daily work.

Table 1. **ypes of Innovation**

Technological	Non-technological
Product innovation refers to advancing goods and services or introducing novel ones to create value for the customer	Marketing innovation regards changing the customers' need, affecting the context in which goods and services are positioned on the market
Process innovation refers to changing ways in which goods and services are created and delivered	Organizational innovation regards mental models, shaping ways of what a company does in terms of management, strategy, and decision-making

Note: these distinctions are also relevant for structuring the findings section.
Source: own elaboration based on (OECD, 2018).

Practically, however, employing AI encompasses a range of challenges related to the implementation and changing of established work processes to facilitate its proper integration, as well as new concerns for privacy and cybersecurity (Chishti et al., 2020). Brooks et al. (2020) even argue that at bigger law firms successful technological change requires a change of the law firm business model altogether. Therefore, technological innovation in the legal sector could be a double-edged sword; on the one hand, it may enhance professional work, but on the other, half-measure implementations may cause counterproductive disruptions. These circumstances could foster a general reluctance toward innovation. Therefore, in the short term, the impact of new technological aids on legal services will be evolutionary rather than radical (Alarie et al., 2018).

We have thus far discussed the instrumental role of KIBS in facilitating innovation in modern economies and their intrinsically innovative nature. Yet, these companies are also very heterogeneous, and there is an observable variance among company-level innovation in different types of KIBS. This holds especially true for legal services; however, it is not due to the lack of digital technologies available on the market or an impending threat of being replaced by machines or AI. Therefore, we find law firms to be interesting outliers among KIBS in their reluctance to embrace technological change in the face of a worldwide digital transformation that warrant further exploration.

Research Context

The literature on this subject has been relatively scarce, and so far, has primarily considered large law firms functioning globally within an English language circle (Brooks et al., 2020). Therefore, we would like to use the example of Poland as a case to illustrate the challenges of a locality outside the scope of law practiced in English as global lingua franca and the problems of small companies that compose most of the local market. In addition, there are two more geopolitical reasons to choose this setting. First, as one of the transformation economies, the Polish case is relevant for other Central Eastern European (CEE) countries, which followed a similar path after 1989. Second, although it is no longer classified as an emerging economy, Poland still harbors the markers of that transformation.

Poland's rapid development over last two decades was followed by growth in international trade, as well as the emergence of new fields of practice in general and business law. Two decades ago, when we established our law firm, it would have been very difficult to imagine Poland as it is today. Early entrepreneurs and investors, their suppliers, advisers, and employees were building economic roles from scratch and, frequently, their innovation and entrepreneurial talents were far ahead of existing legal structures. The realities of the market required precedent-setting solutions, some of which have since become standard legal practice. As the Polish economy developed and the financial market became broader and deeper, the needs and expectations of our clients changed. As transactions became progressively complex, an ever-broader spectrum of legal services was required (Chadbourne & Parke LLP)

Along with this economic momentum, there were progressive changes in professional regulations that loosened the requirements for providing legal advice, subsequently boosting the number of lawyers to 65,000 in 2020 as compared to 23,000 in 2004. However, while the supply of lawyers grew rapidly, the demand remained relatively low with only 14% of consumers and 50% of businesses using legal services in the five years prior to 2017 (Gnusowski, 2017). The level of competition among law firms is even more significant considering law is practiced predominantly by small firms. Large law firms are rare in Poland, with only 36 firms reporting employment of more than 50 lawyers[1] (Rzeczpospolita, 2020), a relatively low rate compared to large law firms in more globally-oriented, Anglo-Saxon countries (Brooks et al., 2020). Furthermore, professional boundaries for competition are almost nonexistent in Poland because solicitors and barristers have very similar rights.

The combination of these factors makes the local legal market very competitive and hypothetically prone to innovate to gain a competitive edge over other providers. Digital technologies are also relevant in this context, as Poland, like other CEE countries, can be characterized as having a modern technical infrastructure (given it was built from the ground up later than in Western countries) and a high social acceptance for innovative solutions (Gnusowski, 2020). Yet, despite competitive pressures and its absorptive capacities for innovation, the legal industry in Poland remains reluctant to embrace technological change and maintains the status quo. This is especially visible in bar associations' policies that restrict promotion and marketing,

Table 2. **LegalTech Taxonomy**

Areas	Functions	Applications
Legal research	Browsing relevant legal resources	Multiple databases and search tools aiding easier and more rapid searches for relevant regulations, decisions, and case law.
Matter management	Billing and legal expenditure management	Serves the ROI assessment to either internal or external stakeholders.
	Knowledge management and expertise automation	Dissemination of legal expertise within the firm to make know-how accessible and useful.
		Automated reporting, standardized workflows, supporting cooperation, boosting research, following precedents, recording approvals.
Contracts	Drafting aids	Automated creation of new contracts.
		Using boilerplates or question-response interfaces to pre-fill relevant data in the new contract.
	Contract review and due diligence	Automated review of existing contracts.
		Risk management based on historic contracts and flagging risky clauses.
	Management	Contract repository, mapping and tracking obligations, task management.
	Analytics	Extraction of contract data to monitor obligations, trends, and efficiency.
Digital signature	Governance and control	Management of electronic documents while increasing speed of authorization.
E-Discovery	Processing electronic evidence	Litigation discovery tools, enabling collection, identification, and AI-supported analysis.
Intellectual Property Rights (IPR)	Management of clients' IPR portfolios	Automated tracking of patents, licenses, trademarks, and other IPR with dedicated tools
Dispute resolution	Managing alternative dispute resolution	Online platforms for arbitrage, mediation, and negotiation, offering cheaper and faster conflict resolutions.
Litigation prediction	Assessing litigation risk	Tools utilizing past court records to predict the outcome of the case, providing a strategic choice between litigation and settlement.

Source: authors based on (Chishti et al., 2020).

[1] "Rzeczpospolita" Law Firm Rank 2020. https://www.rp.pl/Rankingi/307279984-Ranking-Kancelarii-Prawniczych-Rzeczpospolitej-2020---wyniki.html, accessed 15.12.2021.

markedly limiting the use of social media and directed advertising. Therefore, the Polish case fits the profile of the research problem we aim to address, while providing additional explanatory potential regarding innovation at small law firms on the outskirts of the global legal market.

Method

Our aim was to explain the barriers that could account for legal services' lack of engagement with novel digital solutions in day-to-day work, despite their categorization as a KIBS, an otherwise innovative sector (Miles et al., 2019). We focused on small law firms because they are conceptually recognized for different innovative behaviors (Vermeulen et al., 2005) and empirically account for the majority of the Polish legal market. As such, they also provide an opportunity to explore the challenges of locality for legal services that cannot rely on expanding services that require English and the rich market capitalization to grow globally. Law is written and practiced locally, both in terms of the legal regulation system and the language underpinning the legal advice being delivered. Therefore, it is important to observe how such local conditions shape the opportunities for innovation in countries outside the boundaries of the contemporary lingua franca.

In this study, we adopted a mixed-method approach, combining both deductive and inductive inferential modes in a pragmatic manner (Morgan, 2014a) as follows. First, we used elements of quantitative analysis to provide baseline observations (Morgan, 2014b) regarding the specificity of law firms' attitudes toward the use of technology. The main aim of the survey was for lawyers to assess the relevance of 30 success factors extracted from the literature using a 5-point Likert scale (see Box 1). We used survey data collected among 258 companies, which were comprised of individual practices (71%) and small firms (29%; i.e., two to five lawyers). Approximately 25% of the firms were mature companies established before 2005, 44% were founded from 2006 to 2014, and the rest were young firms that opened in 2015 or later. Fifty-seven percent of companies were predominantly oriented toward business-services. Others focused on individual consumers, however it is common for law firms to have mixed client portfolios that change with time, so we consider all of them KIBS. As the results seemed to confirm the cognitive relevance of digital innovation in legal services, we ended up puzzled.

Based on our experience in the field, we were expecting devil-may-care disregard toward novelty among lawyers. Thus, we started wondering whether lawyers actually walk the talk in this regard. In the qualitative part of the study then, we aimed to learn about innovation in its professional context and explore possible discrepancies between positive attitudes toward digital novelty and actual practice among lawyers. We conducted 28 in-depth interviews with individual lawyers. We asked open-ended questions about their daily routines and the use of different tools and technologies. We also aimed to learn more about the subject by non-participant observation of LegalTech Meetup — a small community of law firms that organizes meetings to advance the use of technologies in the legal sector.

Our core premise was to examine situationally detached attitudes reported in our survey, which like other studies, paint the picture of inevitable technological progress (Susskind, Susskind, 2015). Given that we wanted to contrast these postures with actual practices we opted for an inductive mode of inquiry using constructivist grounded theory (Charmaz, 2014). As the way of analyzing either the content of behavior or its cognitive context along the relationship between them, it seems well suited to explore the problems of technological change (Jaehun, 2011). As follows, the grounded approach often elicits unknown heterogeneity or unexpected obstacles to innovative processes (Steensen, 2009). Therefore, given the professional specificity of legal services and the locality of performing them on the peripheries of the global market we found it quite useful to follow principles described by Charmaz (2014). We started with open-coding relevant excerpts in the transcripts to produce six different barriers related to legal innovation. After comparing these barriers, we clustered five of them into two categories (Individual Work and Law Firm Performance) that reflected the alternative ways our interviewees discussed technological innovation. The sixth barrier (Technological Design) was left outside this distinction, as it reflected an overarching problem within technology itself.

Findings

We identified six barriers hampering innovation in small law firms. Five of them were clustered into two categories (Individual Work and Law Firm Performance) mirroring the different ways the interviewed lawyers discussed their relationship with technological innovation. Initial barriers related to individual work included personal affordances, managing uncertainty, and confidentiality concerns. However, an increased workforce and client base among growing law firms revealed new barriers to technological adaptation that focused on the law firm's performance, including adjustment challenges and the cost of implementation. As these two bottom-up categories coincide with a top-down distinction between product and process forms of technological innovation, the findings can be examined within this context. At last, we will discuss the sixth overarching barrier of technology design, rendering slightly different prospects for each path of technological innovation in the foreseeable future.

Box 1. **Selected Survey Questions**

Below are excerpts from the questionnaire used in quantitative portion of the study described in the method section. For the sake of brevity, we included only the questions that were relevant in this particular study.

Question 1.
Assess the judgement: "I think that market position of my law firm will be stronger in the next five years":
Answer options:
- I strongly disagree
- I somewhat disagree
- I neither agree nor disagree
- I somewhat agree
- I strongly agree

Note that this item was used as the independent variable for the step-method regression and the final model presented in Table 3.

Question 7.
Assess the relevance of competition factors listed below (as of 2017 and in the perspective of the next five years). Please select the appropriate number from 1 to 5, where 1 means «completely does not matter», and 5 means «It is very important.»

Competition factors
- Experience, tradition, and history of the law firm
- Reputation of individual lawyers / law firm image
- Specialization in a specific field of law
- Orientation toward a specific market segment
- Low prices of legal services
- Convenient location of the office
- Exterior and interior design of the office
- Aesthetics of personnel attire
- High level of legal competence
- Cooperation with prestigious foreign partner
- Effective administration (e.g., secretariat or archives)
- Low cost of operations
- Adhering to the professional ethics code
- Adjusting business hours for the client's convenience
- Adjusting billing and payment for the client's convenience
- Marketing and promotion activity
- Introduction of new products and services
- Eye-catching website of the law firm
- Positioning the website in search engines
- Online promotion and social media presence
- Blogging and publishing articles on law-related websites
- Digitalization and gaining technological advantages
- Quick and time-efficient service
- Friendly atmosphere in relation to the clients
- Good customer care
- Keeping deadlines and promises made to customer
- Responding to client's expectations
- Ability to instill trust
- Reliability in service delivery
- Ability to give practical advice.

Note that each of the 30 factors was assessed twice (regarding their current and future relevance), accounting for a total number of 60 items. These data were used both in Figure 1, where the temporal dimension of the assessment was distinguished on the x and y axis. These items were also used for a step-method regression and the final model presented in Table 3, where the temporal difference was also marked and stressed in the text.

Source: authors.

Individual Work

When considering attitudes toward innovation, small law firms seem to be aware that technological progress changes the business environment, often reporting a willingness to change how services are produced and delivered (PWC, 2018). In our survey, we found a similar pattern when we asked our respondents to assess both the current and future relevance of technological factors for successful competition and ensuring a good position on the market. As presented in Figure 1, the importance of each factor is expected to grow over the next five years, with a greater importance assigned to value creation factors (i.e., service innovation, technology) and slightly lesser importance allocated to online presence factors (i.e., having a distinctive webpage, webpage positioning, and the use of social media).

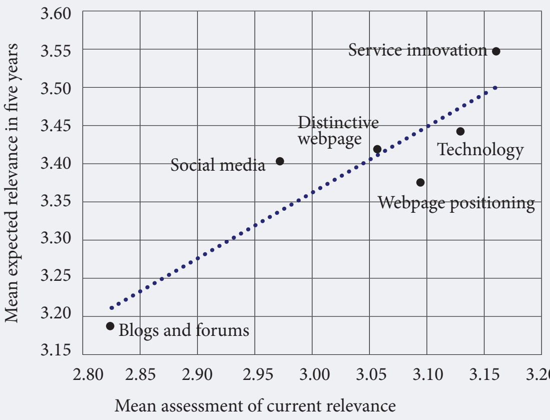
However, as we explored this pattern in our qualitative analysis, we found that these assessments do not necessarily translate into actual practice. It is not surprising that the companies do not always put their words into action (Li, 2016), but our findings provide a focal point to question why that may be the case.

Personal Affordances

Affordance is an ecological concept formulated by Gibson (1982) to capture the convergence of possibilities created by the environment's capacity and actor's capabilities, defining the prospective opportunities for action. This argument was extended by Norman (2013) to account for human-machine interactions, highlighting the role of interfaces in structuring the perception of what uses are available to the actor and to which end. Thus, in principle, people only perform actions that are afforded by their environments, including digital ones where affordances are designed through their programmed internal logic and interfaces. However, an actor's subjective perception of an action's relevance or ease of completion must also be considered simultaneously in a relational fashion (Gaver, 1991).

As previously noted, the innovative spirit emerging around the legal service market has generated many digital solutions to support the knowledge-intensive work of a lawyer (e.g., research, drafting, or managing relationships with clients). Thus, a lack of affordances cannot really be considered a causal factor to explain lawyers' baseline reluctance toward technological change. When we asked about this reluctance, the interviewed lawyers often referred to perceived expectations: "Well, I don't really see that clients who come to us are interested in any form of automation at all. They come to the lawyer, not to the machine, right? For many of these people the personal contact and touch is what really counts, even if it is merely via e-mail correspondence. It's mostly about the questions and they want ME – to answer them – not the machine."

Figure 1. **A Comparative Assessment of the Current and Future Relevance of Technological Factors in Successful Competition**



Note: The study was conducted using a 5-point Likert scale. The reference scale is slightly higher for the Y axis.

Source: own elaboration.

In this case, the environment's capacity is mediated by the actor's optics. The static structure of external expectations finds the value of legal service to be in personal attention and problem-solving. When providing expertise through direct communication is perceived to be the core feature of a provided service, digital solutions that rely on indirect contact are deemed irrelevant. This also highlights a difference between smaller and larger, more innovative law firms that are pressured by corporate clients who demand efficiency and cost-effective service (Brooks et al., 2020) rather than a personal touch. Therefore, we presume the structured cognition of external market expectations to be a relevant factor in explaining innovative behavior.

This perception does not necessarily preclude innovation at small law firms, especially when they start to develop: "our partnership slowly gains pace, and we start to think about enhancements (…) I mean the record of the incoming and outgoing post and… I cannot really explain it well, because when it comes to technical things my partner is better at this (...) but we will outsource that to professionals." However, it is worth noting that even when the need for managing the content of knowledge-intensive work via digital tools is recognized, the lack of technical knowledge about these solutions narrows the scope of their potential applications. Lawyers often lack this technological imagination and affordances remain hidden to them. Therefore, they need to rely on more technologically inclined partners or external professionals, effectively limiting possibilities for the endogenous, spontaneous change that is a driving factor for small firm innovation (Bumberová, Milichovský, 2020).

Managing Uncertainty

The professional work of a lawyer is often filled with uncertainty. The interviewees often reported that their clients usually sought their knowledge and advice when their matters became unbearably pressing and time-sensitive, suggesting that Flood's theorization of a law firm as crisis management (Flood, Mather, 2013) may have a significant merit. Simultaneously, a lawyer's choice of action is often influenced by an external source of decision-making beyond their control (e.g., an unruly adversary, a court of law, or a public office).

According to the literature on organizing (Weick, 1979, 2005; Czarniawska, 2005), facing uncertainty induces episodes of sensemaking that may result with either creating new patterns of response or resorting to proven behavioral schemes. We observed that lawyers tend to rely on routinized behavior to assist memory and adapt to daily challenges. As one interviewee noted, "As a traditional and analogue person, I keep a paper calendar anyway, because if I write something by hand, then I remember it better. I simply like this form, and I am always carrying it with me." In this sense, keeping the paper calendar becomes a psychological resource for reassurance. However, it gets interesting as the quote continues to the subject of managing collective knowledge:

"However, we also have a big calendar on the wall that we print every month and mark meetings, hearings, travels, and those kinds of things. Also, there is the electronic calendar among employees that we did not have before. The assistant is obliged to enter all the deadlines for the letters and organize it for other employees. I control it (...) to organize work of employees, allocate tasks, and monitor the deadlines."

Printing the calendar on the wall is important to facilitate the internal flow of information by considering the collective schedule. Seemingly, the electronic calendar could replace all the others, but instead, it merely supports a new function of managerial control. This limited use of technology illustrates the importance of reliance on proven routines for managing collective knowledge.

As such, the reliance on routinized behavior for a perceived stability of operations does not leave much space for innovation unless new challenges diminish the routine's value:

"We have problems with so called follow-ups (...) When we agree with the clients that they need to give us something, then if we do have time to keep an eye on it then we get it… and if we don't have time, we don't. (...) I realize that we have problems, delayed projects… I have a project list made headlong… We have to-do lists that I need to create, we have to-do lists that I need to keep up with because if we fail, the client will rip our heads off, but it is still a problem. It does not work well."

It was only in this context of crumbling personal practice that two partners started to describe the digital information system they would want to implement to aid their knowledge work (e.g., shifting contexts, keeping up developments, and changing requirements). The measure of reliance on established practice could be an important predictor for conservative behavior among lawyers, until the current practice becomes untenable.

Confidentiality Concerns

The last obstacle from the perspective of individual work is concern about the confidentiality of sensitive information, specifically the storing and handling of digital documents. In the context of big law firms, this problem is discussed as a matter of maintaining foundational trust to create value for the customer (Brooks et al., 2020). We would argue, however, that this concern goes beyond its market worth, given that client privilege is essential to the practice of law, and it is the lawyer's responsibility to keep entrusted information secret.

Many of our interviewees stressed ethical concerns. Holding themselves to a very high standard of confidentiality, the interviewees doubted if digital solution providers were able to match their standards:

"I don't use any system for managing clients because I don't have trust in the providers of those services. The less I put in the external tools, the better it is for me due to the responsibility of professional secrecy in keeping client's data under my care. I feel that at the present stage, service providers are too small to ensure a sufficient level of security. That's why I avoid them even though I have heard that such tools are heavily advertised. So far no one gained enough trust for me to put documentation, evidence and so on in their systems, because I'm afraid that in case of the hack these providers are not able yet to fight off the threat. I don't want to be the one testing if they can do it right and I don't want to explain myself before my clients if they cannot. (...) Well, I could be wrong, but for now I don't use these types of tools."

In this quote, the lawyer stresses the relevance of client privilege first and only then rationalizes his attitude by discussing trust with his clients. Undoubtedly, the two are mutually coupled. However, the underlying ethical obligation forged into a lawyer's professional identity may intensify an aversion to entrusting digital solution providers with privileged information. Given that such technologies create value by processing data, a reluctance to store information hampers the opportunities for product innovation in this KIBS sector.

Law Firm Performance

The distinction between product and process innovation can be blurred in legal services, because the same units of information (e.g., documents, memos, emails, and phone calls) are being used to both execute knowledge-intensive tasks and perform managerial control. In our interviews, lawyers often distinguished these two functions of technological innovation. While often discussing them interchangeably, they primarily considered the possibility of implementing digital solutions as a means of control and coordination of collective work rather than to support knowledge-intensive tasks.

This observation can be extended with a further analysis of the survey data (see above). We performed a regression model using a step method to see which factors of successful competition (see Box 1), assessed by the law firms based on their current and expected future relevance, were able to predict a subjective estimation of the market position in the next five years. Out of 60 factors, only five were determined to be statistically significant and were included in the final model, accounting for a 0.158 adjusted R^2.

Factors 2, 3, and 4 are fairly intuitive to explain. The failure in keeping the commitments on time (2) can endanger relationships with current clients but also prospective ones, given that recommendations are a primary source of business. Although reducing operational costs (3) may seem consequential to lowering prices (4), nothing suggests collinearity. Thus, they shall be taken as independent factors. Considering the content of our interviews, however, lawyers refer to operational costs and difficulties of getting more business (e.g., marketing activity limited by professional regulation) as related but distinct concerns.

The remaining factors are less obvious. It would be reasonable to expect that facilitating preferred payment methods (1) would gain relevance in the future rather than the opposite. Executing receivables, however, was a commonly reported problem because small law firms often provide service to individual consumers who usually seek professional aid once they fall into a financial predicament. Therefore, lawyers often use flat rates that are paid in advance to ensure they will stay fiscally afloat, rendering the customer's needs less important. Additionally, the lesser expected relevance of giving practical advice (5), in turn, resonates with specialization as the preferred model of growth. Specialization is presumed to bring business clients who are focused on getting results, rather than understanding how they were achieved.

These findings resonate with our earlier observation that innovation results from necessity in the stage of company growth, when the increasing volumes of clients, workload, and employees diminish the value of the established organizational structure. Our study indicates that lawyers seem to be prone to introducing process innovation for internal information flow, division of labor, and managerial control. Such solutions may be a steppingstone for altering the performance of knowledge-intensive tasks (e.g., filing and data organization systems, facilitating standardization, cross-referencing case solutions and outcomes). However, the barriers of technological adaptation for organizational performance are qualitatively different from the technological opportunities for individual output and come with a unique set of obstacles from the law firms' perspective.

Problem of Adjustment

Coordinating the work of a lawyer is a complex endeavor. Most law firms provide services for multiple clients, cases, and projects, which are often fragmented over time due to the slow pace of court proceedings, administrative procedures, and contract negotiations. Lawyers must skillfully manage their workload, deadlines, and memory to ensure quality service delivery. Digital innovations are particularly instrumental in managing a company that has reached a certain size:

"Let's say that there are about 200-300 active clients on an ongoing basis. There is no way to remember all those discussions and agreements. Besides, you need to organize work so that people can replace each other. Somebody might get sick, somebody might get a day-off, somebody might resign… all sorts of things might happen. Had we just one person to manage finances, then if s/he got sick then nobody would handle the chaos that would arise. The pen and paper method—even if we are not that big of a company—would no longer pan out."

As this quote illustrates, the division of labor that comes with growth increases the level of interdependence that is needed for organizational performance.

In this context, the digital innovation meant to handle these organizational processes needs to match the corresponding degree of complexity. As one lawyer who had just implemented new software in his firm explained:

"The system consists of many elements. Of course, there is a calendar reminding us of what we must do, and we keep different things there: situations we register, conferences, trials, notary public visits, public office appointments, meetings with clients. They are divided between employees, letting us monitor individual workloads and if they have time to be assigned another task. There is other module for planning tasks and monitoring. If they are tasks are done the system requires making annotations for accounting and billing. The billing module, is also there, so as a financial module, where each client has a different payment model. We can also assign different models for different cases. As a rule of thumb, we charge hourly rates, unless the client negotiates other terms. Then, we create a case and apply flat rates or caps, or… the combinations are infinite because clients have an endless number of ideas, and we just try to meet their expectations."

The difficulty of adjusting digital systems to support law firm performance is relevant because lawyers expect complex solutions to match their complex problems and often do not find the existing systems sufficient. The aforementioned law firm settled with that solution out of necessity: "For now, we use (name of the system) because, despite it's relatively obsolete, it meets our expectations best, right? Although it's relatively slow due to technology and it isn't web-based, which is a pain for us, it's simply functional, and we have good support from developers so that any problem is being fixed almost on the spot." Other companies, however, often reported that this lack of adjustment to the specificity of legal services was the reason implementation was postponed until a better solution could be found.

Implementation Costs

The problem of adjustment was often followed by a discussion of implementation costs. A lawyer's workload comes in waves when intense surges of work are followed by temporary periods of calm. Furthermore, legal work often plays an intermediary role in the relationship between the client and other parties; thus, the work is mostly reactive to external decision-makers like courts, public offices, client's partners, or litigants. Effectively, lawyers have very limited control over their schedules.

Table 3. **Regression Model Explaining Predicted Market Position in Five Years**

Model			Coefficients				Multicollinearity	
			Beta	Standard error	Standardized beta	Sig.	tolerance	VIF
Current		(Constant)	2.735	0.399		0.000	—	—
Current	1	Providing customers with preferred payment methods	–0.134	0.055	–0.165	0.016	0.815	1.345
Current	2	Keeping the commitments on time and informing the client about ongoing changes	0.370	0.095	0.326	0.000	0.533	1.299
Future	3	Low operation costs	–0.257	0.062	–0.293	0.000	0.744	1.226
Future	4	Low prices of services	0.242	0.056	0.301	0.000	0.770	1.876
Future	5	Capability of giving the client practical advice	–0.380	0.105	–0.298	0.000	0.552	1.812

Source: authors.

In this context, time is perceived as a very limited resource, and although a digital system may eventually help to save time, there is also a learning curve:

"Before, I was entering everything into Excel… I had millions of excel sheets to record my work time or things I had to do for the given client. Managing all of this started to make things take longer so I implemented this software to have everything in one place. (...) That really made things better although… I mean, moving onto this software is difficult because you need to learn to put in everything in that one place. But if you really start to use it, then it actually saves time."

As this case illustrates, the effective use of software requires attention and a time investment to learn a new way of managing work. Lawyers who were reluctant to use digital solutions often cited time as a resource they simply could not afford to lose.

The cost of time is not only limited to the initial effort to learn the software, as software also requires regular maintenance:

"(In the context of organizing work) Well, this is a problem for us that I try to tackle it with apps like (task management software) and such. I try to use them, but unfortunately you need to work on it all the time to see some effect. That is difficult and wearisome, even more given that we have a lot of work, a lot of things happen… and it's like an overflow."

Ensuring the reliance of digital solutions becomes an imposition on the lawyer's time-management routine. For small law firms that have limited control over their schedules, the subjective cost of commitment to these process innovations compounds over time.

Even if lawyers feel overwhelmed and recognize the need to alter their ways of organizing work, they often put off the implementation of digital technologies, especially when their concerns coincide with the problem of adjustment:

"I have two ideas that I'd like to implement that already are out there, however they do not work as they should. In other words, we should sit on it and figure it all out anew. I realize that this would cost tens or even hundreds of thousands, so this is something rather for the future… two or three years before we will get to this."

Although the matter of financial costs have been reported to be a significant barrier to innovation among lawyers (LegalTech Polska, 2018), our interviewees rarely brought it up without prompting. The implementation costs were mostly discussed in terms of the amount of time required to maintain or implement the digital technologies.

Technology Design

Technological innovation is relational in that it is not only the user's attitudes or decisions that matter for adoption, but also the qualities of the digital solutions. These qualities may facilitate or hinder dependence on the tools, and lawyers seem to be particularly sensitive to their shortcomings. This is especially true for products meant to support knowledge-intensive tasks in individual work. Apart from the issues of personal affordances, routine reliance, and confidentiality concerns, the technology is not always able to perform operations using specialized language in a sufficient way.

During one of the LegalTech meetups, one of the participants made a presentation on testing different contract analysis tools for a large international corporation. He stressed the necessity of manually training each individual software to provide the machine-learning algorithms with relevant information to evaluate the risky phrasing in legal clauses. The software itself cannot realize what is important without human input, and even if it recognizes the patterns of general language, it does not 'understand' the meaning behind it. This is especially relevant for the intricacies of legal language, in which certain terms have highly specific meanings. Thus, the software can only provide statistically appropriate guesses to flag certain clauses based on dictionaries that still have to be continuously maintained and evaluated by the lawyers.

To understand the bigger picture of digital innovation within the legal sector of KIBS, three additional factors must be considered. First, the natural language processing (NLP) responsible for part-of-speech tagging is only as good as the corpus it employs. This is foundational for language operations, and although such resources are well developed for English due to its global scope, support for more local and nuanced languages are still far from perfect (Kobyliński, Kieraś, 2018).

Second, even if the algorithm can distinguish between words in general, it still needs to be trained to for the specialized context through linguistic models to recognize true meanings and relationships among extracted terms. In the long-term, NLP software may enable legal analysis to be performed more quickly and thoroughly. However, it cannot replace the professional work needed to train, update, and evaluate outputs on an ongoing basis. Big international corporations may be able to afford such maintenance due to economies of scale on the user's side, but small law firms may lack the time to invest in such augmentation.

Third, updating and evaluating this output could be made easier with further economies of scale on the provider side, in which individual users train the algorithm for use by others, while also using the technology for their own benefit. While this is already being done to some extent, the lawyer running the presentation also stressed that legal work is sensitive to the style of legal advice and client-specific tolerance of risk. Therefore, it is very unlikely for there to be a one-size-fits-all digital solution. Product innovations would have to adjust to varying degrees of complexity, stemming from the professional preference and nuances of the legal work.

These limitations are less prominent among process innovations meant to aid organizational performance.

Numbers, dates, logical variables, classes, and objects that are employed to represent different aspects of the organization are less complex and easier to process. Given that these types of systems are less difficult to design, there are many more managerial tools available on the market than digital solutions meant to assist knowledge-intensive tasks. Legal work is inevitably local because of geographically specific regulations and the language of the country. Therefore, until language processing capabilities, particularly for non-English speaking countries, become more advanced and readily available, the opportunities for technological innovation will be steered more toward managerial control and coordination of knowledge-intensive work.

Discussion

We started this study by questioning why companies in the legal industry introduce notably fewer technological innovations than other KIBS. We explored barriers to innovative technological adoption in the context of Poland's legal sector, a transformation economy dominated by small law firms. We also highlighted the challenges of a locality on the peripheries of the global legal market delimited by the scope of the English language and rich capitalization of international corporations.

Based on our study, we identified six different barriers to technological adoption in the legal field: three reflecting the character of a lawyer's individual work, two related to the law firm's performance, and the overarching problem of technology design. Although it has been reported that legal companies tend to introduce rather non-technological forms of novelty (Miles, 2005), we also observed that when it comes to digital technologies, firms preferred to implement process rather than product innovation. The consistent expectations of local customers do not push small law firms to imagining new forms of value creation as global clients do. Brooks et al. (2020) discussed this phenomenon in terms of a skills gap. However, we would argue that it is not only about learning how to use digital enhancements but also determining their practicality.

This is especially true in cases in which the value of reliance on existing practices renders technological disruption counterproductive. However, as a company grows, there is a tipping point when the volume of clients, workload, and employment exceeds the mental and organizational capacities of individual lawyers. In such situations, law firms experience endogenous pressure, pushing them to introduce process innovations as a measure of control and coordination of knowledge-intensive work. Thus, the observed reluctance among lawyers to adopt technological innovations should not be assumed to be mere conservatism, because the implementation of digital novelty follows the value of reliance and stability in managing legal work.

In this context, we concur with Brooks et al. (2020) that LegalTech software does not seem to change the character of legal work, as suggested by other authors (Susskind, Susskind, 2015). Rather, it is deployed to automate repetitive administrative tasks and managerial control. This, of course, might augment the performance of legal tasks by ordering content and disseminating knowledge about working solutions to typical problems, but it does not change the practice itself.

More substantive technological innovations in countries outside the global scope would require advancements in the processing of natural and specialized language in languages other than English. Legal work is an inevitably linguistic endeavor built on the foundation of local meaning and systems of law that cannot be easily captured, let alone interpreted, without professional expertise. Currently, the maintenance of machine-learning algorithms to work effectively demand a time investment small law firms simply cannot afford.

Therefore, we expect that small clusters of larger companies will have to tread paths for digital enhancements in the legal sector. By spearheading innovation, they may effectively strengthen their local position by capturing more business clients who demand cost and time efficient services rather than relational and personal concern as individual consumers do. Consequently, these companies may alter the market structures in countries where small law firms depend heavily upon the business portion of their client portfolios. As follows, the larger players will be able to grow due to economies of scale and push the boundaries of technological novelty.

However, we do not expect such an endogenous change to happen soon—especially in Poland, where the partner model of legal corporations has not developed as extensively, and the ethos of professional independence supports the fragmentation rather than agglomeration of the legal service industry. We believe that the overall acceptance of digital technologies may be positively moderated locally by the scope of public sector implementations concerning the digitalization of registers, procedures, and information flow. In private sector relations, technological innovation in the legal field is more likely to travel exogenously through backchannels of cooperation networks, connecting law firms from different countries to work together on cross-country agreements. Furthermore, established LegalTech providers will eventually translate their solutions into languages across less lucrative borders to expand their markets.

We believe that in the foreseeable future, the legal sector will remain an outlier in technological innovation as compared to other KIBS who rely more on processing numbers (e.g., finance, accounting, consulting) and images (e.g., architecture and marketing) to enhance services. This concerns countries on the outskirts of the global legal market in particular, where law by being practiced in local languages other than English will require additional efforts in adopting novel solutions. Small companies would not be able to afford this premium, so they will avoid digital innovation until it becomes *'a new normal'* created by a small cluster of innovators, accompanied by the public sector's digital transformations. However, we caution against assumptions that the field is simply adverse to technological progress. Rationalized concerns regarding the usefulness, reliance, trust, fit, and maintenance of digital solutions hint at a more reflective consideration of the drawbacks caused by creative disruption, given the value of the stability that legal services provide to other sectors of the economy. There are ideas whose time is yet to come. So an aloof behavior towards novelty may not necessarily mean turning an irrationally blind eye towards these developments as much as estimating the right timing. No one than a lawyer is bluntly aware that inaction is as much of an action as the action itself.

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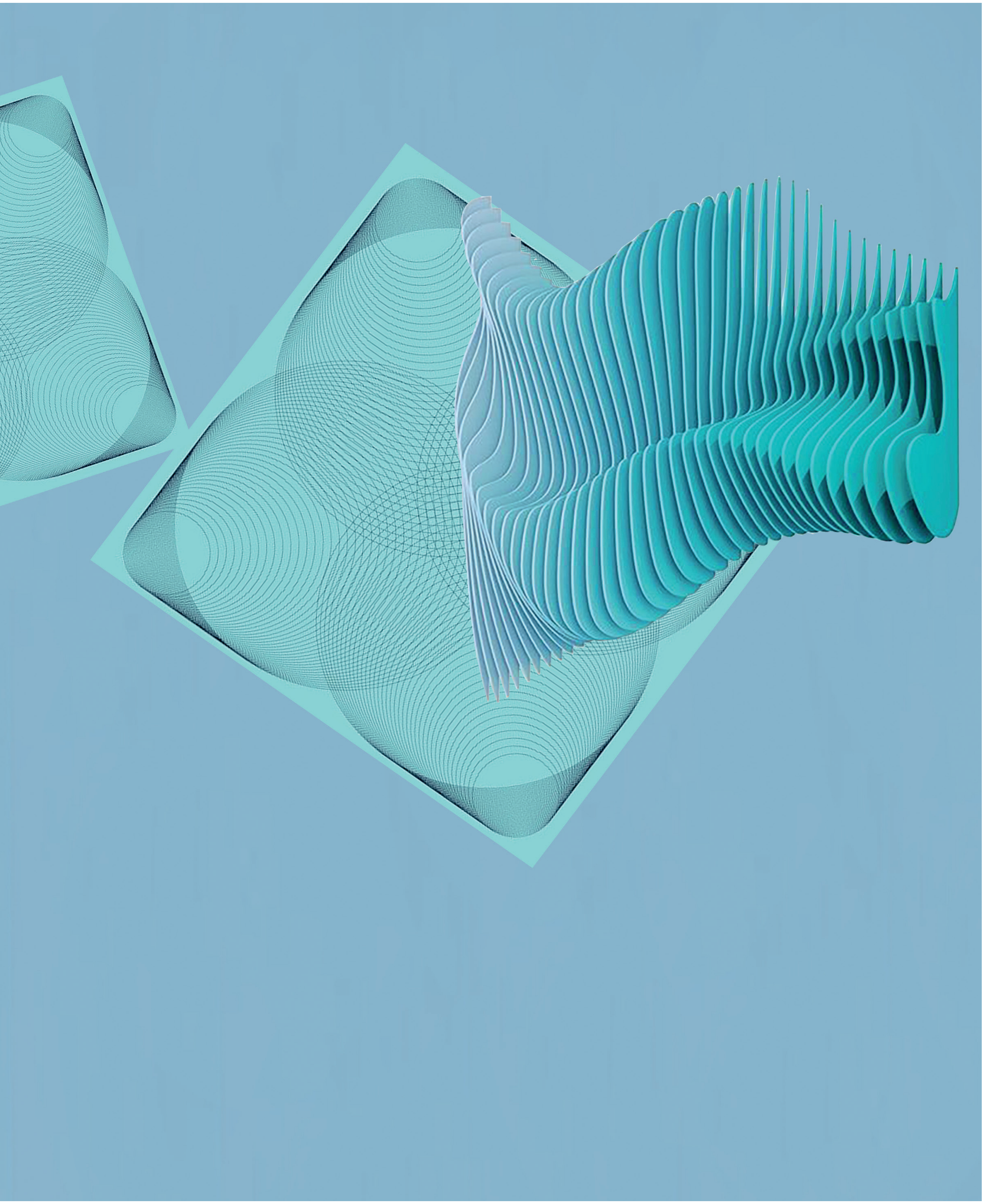

Determinants of Foresight Maturity in SME Enterprises of Poland

Anna Kononiuk
Assistant Professor, a.kononiuk@pb.edu.pl

Bialystok University of Technology), 45 A Wiejska Street, 15-351 Bialystok, Poland

Abstract

The complication of the business environment, the growth of uncertainty and the dynamics of change significantly affect strategic planning in business. Foresight research used in a company serves as a link between the volatility of the surrounding environment, possible expansion prospects and an enterprise's strategy and tactics. Based on data from Poland, this article examines the main factors that determine the readiness of small and medium-sized enterprises (SMEs) to navigate a variety of paths into the future (foresight maturity). This study integrates concepts of foresight maturity, dynamic capabilities, and corporate foresight. It relies on a sample of over 500 Polish manufacturing SMEs that is representative in terms of size, type, sector and geography of activities. Using a 28-criteria assessment tool, it was found that the level of foresight maturity of a company most often depends on the size, type and geographical coverage of markets. Involving stakeholders in the development of corporate strategies, scanning the micro- and macro-environment of the enterprise using a variety of information sources, improving skills in working with foresight tools as well as fostering other dynamic capabilities enable to gain lasting competitive advantages in a changing and unpredictable business landscape.

Keywords: foresight; dynamic capabilities; foresight maturity; organizational foresight; exploratory factor analysis; determinants of foresight maturity

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Introduction

The dynamics involving the uncertainty and complexity of the environment and trends affecting business activity, such as the Covid-19 pandemic, widespread automation and digitization (Spencer et al., 2021), the mismatch between education and labor market needs (McGuiness et al., 2017, Cedefop, 2018), as well as the rapid pace of innovation (Parry et al., 2009), shorter production cycles, and new customer requirements, make it difficult to anticipate business growth. In Western countries, the anticipation of enterprise development is widely endorsed by organizational foresight, which has become a yearly practice for many organizations (Hodgkinson, Healey, 2008; Vecchiato, 2015).

Foresight research used at a company serves as a link between the volatility of the surrounding environment, possible expansion prospects, and an enterprise's strategy and tactics (Derkachenko, Kononiuk, 2021). From the perspective of the theory of evolutionary economics, which analyzes the development of a company in its movement (Nelson, Winter, 1982), foresight implemented in organizations is perceived as a part of the search and change strategy, i.e., as a dynamic capability (Rohrbeck, 2010). Dynamic capabilities, in turn, are learned and stable patterns of activity through which the organization systematically generates and modifies its activities and adapts to new environmental conditions (Zollo, Winter, 2002).

Although there are many foresight initiatives run worldwide, foresight research carried out by small and medium companies is still weakly documented. As Iden et al. note, this study field is still underdeveloped, poorly organized, and characterized by exploratory studies, usually involving case studies, which are used to produce arboreal models to structure and synthesize empirical findings (Iden et al. 2017)[1]. On the other hand, SME enterprises make essential contributions to economic growth and employment and constitute 99% of all enterprises in OECD countries (OECD, 2019). Therefore, the foresight research which could stimulate those companies for growth and further development should be their part of a strategic research portfolio.

This study demonstrates a quantitative approach to the concept of foresight maturity. By foresight maturity the author understands a set of highly valued, learned, repetitive organizational behaviors (capabilities) in anticipation of the future, which make the company function better on the market than its competitors. This study aims to determine, using exploratory factor analysis, the main dimensions of foresight maturity at SME companies. The survey, conducted using CATI technique, was executed on a sample of 511 SME companies of the manufacturing sector. The theoretical background of the article integrates three research themes: dynamic capabilities (Winter, 2003), corporate foresight (Rohrbeck, 2010; Rohrbeck, Gemuenden, 2011), and foresight maturity models (Grim, 2009).

Literature Review

Dynamic capabilities

Dynamic capabilities were first comprehensively described by Teece et al., who pointed out that an organization is constituted not only by resources, but also by mechanisms for the formation and use of habits and capabilities (Teece et al., 1990). Dynamic capabilities allow for internal and external skills, resources, and competencies to adapt, integrate, and reconfigure to meet the demands of the environment. Zahra et al. state that dynamic capabilities are used by organizations to build business strategies, enter new markets, acquire new competencies, commercialize new technologies, and thus increase the speed of response to changes in the organization's environment (Zahra et al., 2006). Discussing the origins of dynamic capabilities, Zahra et al. relates the concept's assumptions to evolutionary economics (Nelson, Winter, 1982), arguing that managerial decision-making under conditions of uncertainty and bounded rationality leads managers to seek satisfactory rather than optimal choices. Zollo and Winter claim that dynamic capabilities are an established collective activity as a result of organizational learning, by means of which the organization systematically generates and modifies its operational routines in the process of seeking to improve the effectiveness of its management system (Zollo, Winter, 2002). According to Wang and Ahmed, dynamic capabilities are an organization's orientation toward integrating, reconfiguring, renewing, and reconstructing the competencies of the enterprise, in particular improving and reconstructing key capabilities, directed toward responding to the changing environment and maintaining competitive advantage (Wang, Ahmed, 2007). These capabilities allow the organization to create, expand, or modify its resource base. In clarifying the concept of dynamic capabilities, it is worth pointing out their characteristic features, which include (Jashapara, 2004):

- universality – dynamic capabilities can be applied in different contexts and industries;
- specificity – organizations can use similar, in essence, dynamic capabilities, and differences at the level of detail provide opportunities for competitive advantage;
- equifinality – understood as reaching the same goal by many different ways; organizations develop similar dynamic capabilities even if they have different starting points and choose different development paths; developing similar dynamic possibilities by different companies under condi-

[1] In the Polish research on the subject, there are only fragmentary studies relating to the use of foresight in enterprises (Nazarko, 2013; Kononiuk, 2014; Kononiuk, Sacio-Szymanska, 2015).

tions of uncertainty and a multivariate future is achieved by engaging different competences by the enterprises;
- prototyping – dynamic capabilities provide the ability to verify and acquire new knowledge at relatively low cost and risk;
- real-time information – dynamic capabilities enable adaptation and adaptation to the changing context of the environment;
- multiple options – dynamic capabilities point to alternatives that provide managers with the ability to react quickly to changes in the environment.

Complementing the characteristics of dynamic capabilities, it should be noted that Augier and Teece revised their earlier definition, assuming that dynamic capabilities, which are higher-order competencies, not only provide the ability to respond to changes in the environment, but also determine these changes (Augier, Teece, 2009). Shaping pertains to an organization's capacity to deliberately shape market opportunities in order for the organization to gain a lasting competitive advantage. The act of shaping the environment is linked to the entrepreneurial attitudes of managers who, through their actions, influence changes in the organization's environment. Interesting examples of market shaping are the business models of Starbucks and Netflix. Starbucks counterbalanced its competitors' low entrance barriers by shaping the culture of coffee drinking. Its business model was not just about drinking coffee itself, which could be done more comfortably and less expensively at home, but about building the whole experience of cosy atmosphere and sharing of this experience with other customers. Another example of influencing trends in the environment is that of Netflix, which expanded its DVD by mail business model into the ability to watch movies instantly on personal computers, leading to the demise of Netflix's main competitor Blockbuster, which was unable to shape changes in the external environment at a sufficient pace (Agwunobi, Osborne, 2016). In line with Rohrbeck and Paliokate and Pacesa, who perceive foresight as a dynamic competence (Paliokate, Pacesa, 2015; Rohrbeck, 2010), in this research paper I shall argue that foresight maturity could be treated as part of a search and change strategy, i.e., as a dynamic capability.

Corporate foresight

The research in this field is dominated by case studies or the use of foresight at large companies; therefore, small and medium-sized companies are still a white spot in this field. Of the many definitions of foresight, the one that best reflects the nature of its implementation in a company is Rohrbeck's definition, which treats foresight as the capacity of the enterprise to identify and evaluate discontinuous change, activating management practices to ensure the long-term survival of the business (Rohrbeck, 2010). Iden et al. complement this definition with the aspect of systematicity and building alternative visions of organizational development, treating foresight as a systematic approach to learning and understanding possible futures and building shared visions, and is aimed at guiding and enabling present-day decisions (Iden et al.,2017). Still, Hojland and Rohrbeck. conceptualize foresight carried out at companies as the combination of perceiving, prospecting, and probing acts carried out at the enterprises. Perceiving is expressed in the application of key practices that encourage the exploration of new business areas by enabling the identification of driving forces. Prospecting is about understanding the implications of driving forces at both the individual and collective level whereas probing is to undertake activities that allow for the validation of value propositions, product and service development, and market reception (Hojland and Rohrbeck, 2018).

It should be stressed that foresight at a company should be treated as a process and not just a set of techniques for anticipating the future. It is a procedure based on consultation and constant feedback (Ejdys et al., 2019). Secondly, the starting point in foresight research is the assumption that there are many alternative future states (futures) (Kononiuk et al., 2017). The type of future the company chooses depends in some part on the decisions that are made today. Hence, foresight refers to a proactive approach towards the future. Furthermore, the purpose of strategic foresight is not to predict the future, but to prepare a company to recognize future changes in its environment and to respond to them in advance (Patton, 2005). Strategic foresight supports companies in understanding the complex driving forces which are the agents of change in their environment and enables them to adapt their strategies and R&D departments to the changing conditions of the environment in which they operate. It enables anticipatory intelligence to be built: reducing uncertainty by identifying trends and weak signals (Rohrbeck, 2010). The identification of weak signals coming from the environment allows for sensitizing the company's sensors to signals coming from outside, thus the company gains new knowledge about the phenomena occurring in its environment. If it gains this knowledge earlier than its competitors, the range of uncertainty of functioning in the environment decreases, especially as weak signals become strong signals with the passage of time (van Veen, Ortt, 2021).

The main goals of foresight carried out at companies are: identification of potential business areas and new markets for business development (Daheim, Uerz, 2006), supporting and stimulating innovation processes at the company (Day, Shoemaker, 2005), and supporting decision-making processes at the company (Hines, 2006; Fink et al., 2005). Based on the implementation of a survey on a sample of 230 small, medium, and large industrial processing companies in Lithuania, Paliokate and Pacesa demonstrated that foresight has a positive impact on both exploratory and exploitative innovation (Paliokate, Pacesa, 2015).

According to an investigation of SME companies, which constitute a Russian medical technology cluster, the authors (Milshina, Vishnevskiy, 2018) concluded that foresight projects provide SMEs with an opportunity to overcome constraints to identify potential technology chains that can be translated into innovative priorities and indicators to build credible visions of the future of SMEs. Although in Polish practice it is difficult to discern a comprehensive, cyclic application of foresight research in SME enterprises, it is possible to identify practices undertaken by companies in the scope of future preparedness. The author's intention is to identify these practices at Polish small and medium industrial processing companies.

Foresight maturity models

Maturity models, based on predictable patterns of development and organizational change, are represented by the theory of evolving organizational capability stage by stage (Jurczuk, 2019; Bukowski, 2019). The concept of maturity can be understood as a state of completeness, perfection, and readiness. According to Andersen and Jessen, maturity is a state of specific excellence enabling the achievement of set goals (Andersen, Jessen, 2003). This condition can be viewed through the prism of the organization's ability to manage selected areas of the business that translate into the achievement of strategic objectives (Jurczuk, 2019). Defining maturity in terms of the dimensions of its assessment, Paulk et al. note that maturity is the extent to which the activities undertaken in a company are clearly defined and measurable (Paulk et al., 1993). A transition to a higher level of maturity can be seen through the lenses of the company's acquisition of new capabilities. To date, two foresight maturity models can be identified in the literature. The first one is the Foresight Maturity Model developed by Grim (Grim, 2009). The model was developed taking into account the framework posited by Hines and Bishop (Hines and Bishop, 2006).

The FMM model assumes the assessment of the processes run in the enterprise in accordance with the best managerial practices identified on the basis of external benchmarks. The model is evolutionary, which means that a higher degree of maturity could be obtained after a lower degree of maturity has been reached. The FMM model developed by Grim takes into account such dimensions (referred to by Grim as disciplines) of the company's functioning as: leadership, framing, scanning, forecasting, visioning, and planning. The characteristics of these disciplines are represented in Table 1.

Each of the disciplines mentioned in the FMM models is measured against the scale of activity, which allows one to achieve the preferred outcome. The disciplines could be treated as the areas of foresight activities within companies. The author of the FMM model developed a specific matrix that provides foresight maturity indices for each level of maturity in the identified area. The higher the outcome of the practice, the greater the level of foresight maturity (Grim, 2009).

The second model of foresight maturity (the Corporate Foresight Maturity Model) was developed by Rohrbeck (Rohrbeck, 2010). The model consists of three main parts – context, capabilities, and impact. The context is compiled in terms of six criteria: size of company, nature of strategy, corporate culture, source of competitive advantage, complexity of environment, and industry clock speed. The capabilities are deployed to assess the foresight system in terms of its power in identifying, interpreting, and replying to discontinuous changes. In this context, the maturity level in each dimension of the capability can be used to lead improvement projects. The capabilities are divided into five different dimensions (Rohrbeck, 2010):

- information usage – definition of the type of information entered into the corporate foresight system;
- method sophistication – description of methods employed to interpret information;
- people and networks – description of individual employee characteristics and the networks the company uses to communicate information and foresight;
- organization – illustration of how information is gathered, interpreted, and used within the organization;
- culture – illustration of the importance of corporate culture in supporting or hindering forecasting activities.

The impact is applied to evaluate the type of outcome or added value achieved by corporate foresight activities. The impact is segmented into four categories: reduction of uncertainty, triggering internal actions, influencing others to act, and secondary benefits such as, for example, organizational learning. Reduction of uncertainty measures the extent to which uncertainty in the environment has been made manageable. Triggering internal actions assesses the number of actions that have been initiated in the enterprise as the opposite to influencing others which describes the number and value of actions that have been generated outside the enterprise, whereas secondary benefits measures effects that are not primary goals of the company's activity but constitute extra value for the enterprise. (Rohrbeck, 2010).

In each dimension, there are three to five criteria against which the maturity of the foresight system can be assessed. The conclusions from the practical use of FMM by the author of this article for the assessment of the foresight maturity of enterprises posed some difficulties for interpretation. For example, the forecasting dimension of the FMM model is based on the assumption that there is more vision for the development of an organization, whereas traditional foresight assumes trend extrapolation which refers to a single point in

Table 1. **Disciplines of the Foresight Maturity Model**

Discipline	Characteristics
Leadership	Expressed in the involvement of many employees in the creation of a vision of the development of the organization. A collection of good practices conducive to the implementation of foresight research capability.
Framing	Creating a framework within the company that enables the creation of alternative future states. Establishment of boundaries and scope of activities.
Planning	Positioning and using organizational resources to implement desired visions of the company's development. Providing plans, people and skills to support the implementation of the organizational vision.
Scanning	Gathering and analysing relevant data that contribute to the growth of the organisation.
Forecasting	It is expressed in the assumption that there is more than one vision for the development of the organization. Each development alternative creates unique implications for the existing state of the organization.
Visioning	It is expressed in creating the desired vision of the future and related ideals and values.

Source: (Grim, 2009).

time that can be determined by methods that forecast linear and non-linear trends (Paliokate et al., 2014). Furthermore, some of the disciplines seem to overlap in meaning, e.g., leadership, which is expressed in the involvement of many employees in the creation of a vision of the development of the organization, and the visioning dimension.

In turn, the dimensions of the model proposed by Rohrbeck (Rohrbeck, 2010) were developed on the basis of qualitative research conducted at large companies and refer to corporate foresight. Hence, the author of this article intends to develop dimensions of foresight maturity dedicated to small and medium-sized enterprises which are based on variables validated in a quantitative study.

Research Methodology

The implementation of the actual study was preceded by the construction of a questionnaire, which contained 36 statements relating to foresight capabilities of the company (assessed on a seven-point Likert scale, where 1 – meant that a respondent strongly disagreed with the statement, and 7 – that the respondent strongly agreed with the statement) relating to future-oriented activities run in enterprises. Detailed statements were prepared on the basis of the literature review referring to different and dispersed activities of organizational foresight. The representativeness of the sample and reliability of the results gathered were ensured by commissioning the execution of a nationwide survey to a professional research institution – IPC Research Institute Sp. z o.o. The research activity and elaboration of the results were carried out in the period July 2019-April 2021. The measuring scale finally included 36 variables (Table 2). The criteria of factor selection involved their popularity and significance for organizational foresight in the existing published works.

The actual survey was preceded by a pilot survey, that assumed success in obtaining a representative sample allowing for the generalization of the results for the entire general population

The study covered a total of 511 SME industrial processing enterprises operating in Poland, which included 5% of the enterprises of the surveyed population. At the time of designing the survey, the number of manufacturing enterprises in Poland was 203,521.[2] Assuming a confidence level of 0.95 and a maximum permissible error of 5%, the minimum sample size determined for the overall population was 383. Owing to the involvement of an external research institution, 511 SMEs were recruited for the survey.

The companies participated in the survey voluntarily and their responses were anonymous. The survey questionnaire addressed at innovation department managers and business owners included general information on future-oriented activities undertaken by companies, an assessment of the company's foresight maturity factors, and a metric. Table 3 represents the distribution of surveyed enterprises by size, type and area of activity, while the Figure 1 demonstrates the structure of enterprises by the area of activity.

Quantitative research was carried out using the CATI technique supported by the CAWI technique. The choice of the CATI technique was dictated by the need for personalized contact with innovation department managers or business owners. The CAWI technique was chosen because of its advantages which include: the ability to survey a relatively large group of respondents, a relatively short time needed to conduct the survey, the anonymity of the survey, and the low cost of the survey (Gulc, 2020).

Exploratory Factor Analysis

Exploratory Factor Analysis (EFA) was used to analyze the collected data, allowing one to detect the structure of relationships between observable variables and extract a small number of hidden variables – factors (dimensions) that cannot be directly measured. Before

[2] https://stat.gov.pl/en/, accessed 16.10.2022.

Table 2. **Capabilities of a Company that Characterize Foresight Maturity**

No.	Code	Description	Sources
1	(var_1)	Identifying trends in the microenvironment	(Ruff, 2015)
2	(var_2)	Identifying trends in the macroenvironment	(Vecchiato, 2015)
3	(var_3)	Identifying signs of technological breakthrough	(Rohrbeck et al., 2007)
4	(var_4)	Identifying subtle signs of change (weak signals)	(Hiltunen, 2013)
5	(var_5)	Identifying wild cards (low probability and high impact events)	(Mendonca et al., 2009).
6	(var_6)	Thinking out of the box about the products	(Sarpong, Maclean, 2011)
7	(var_7)	Thinking out of the box about the services	(von der Gracht et al., 2010)
8	(var_8)	Thinking about business activity in a reflexive way	(Sarpong, Maclean, 2016)
9	(var_9)	Managing change effectively	(Merzlikina, Kozhanova, 2019)
10	(var_10)	Recovering from turbulence in the organizational environment	(Edgeman, 2015)
11	(var_11)	Thinking about the company in a systemic way	(Weissenberger-Eibl, 2019)
12	(var_12)	Building networks within the organization	(Wolff, 1992)
13	(var_13)	Building networks outside the organization	(Rohrbeck, 2010)
14	(var_14)	Building alternative scenarios	(Bradfield et al., 2005; Wack, 1985)
15	(var_15)	Matching scenarios them with organizational strategy	(Grim, 2009)
16-20	(var_16) – (var_20)	Involving employees or external stakeholders in setting the vision or mission of the company's development, as well as involving them in product development	(Kononiuk, Glinska, 2015; Inayatullah et al., 2013; Calof et al., 2017; Ruff, 2015; Wind, Mahajan, 1997)
21	(var_21)	Using roadmapping	(Strauss, Radnor, 2004),
22	(var_22)	Using mathematical models	(Chung, 2004)
23	(var_23)	Using Delphi method	(Rowe et al., 2005)
24	(var_24)	Identifying future customer expectations	(Rohrbeck et al., 2007)
25	(var_25)	Having a holistic view of the industry	(Saprong, Maclean, 2016)
26	(var_26)	Creating long-term objectives consistent with the vision and mission of the company	(Grim, 2009)
27	(var_27)	Developing a system of indicators for goal achievement	(Grim, 2009)
28	(var_28)	Valuing teamwork	(Ruff, 2015)
29	(var_29)	Creating a climate conducive to innovation	(Grim, 2009)
30	(var_30)	Promoting the free and transparent flow of information	(Rohrbeck, 2010)
31	(var_31)	Participating in the activities of professional trade associations	(Ansoff, 1975; Hansen, 2006)
32	(var_32)	Participating in prestigious scientific conferences	
33	(var_33)	Collecting information about patents	
34	(var_34)	Reading specialist scientific journals to keep abreast of the latest trends affecting the development of the industry	
35	(var_35)	Searching the Internet and other media constantly for trends shaping the development of the industry	
36	(var_36)	Conducting expert research in the form of surveys, focus groups, individual interviews in order to identify trends affecting the development of the industry	

Source: author.

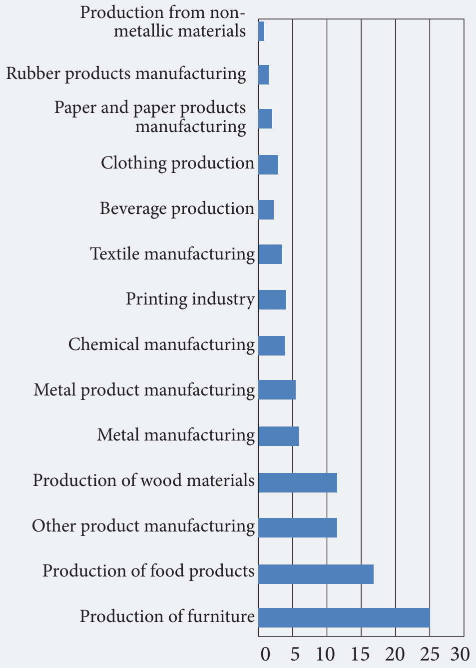
starting the exploratory factor analysis, the basic conditions of its use were checked. Maiser-Mayer-Olkin and Bartlett tests were carried out, which confirmed the good properties of the data (Bedyńska, Cypryańska, 2013)[3].

Next, correlation analysis was conducted between the studied variables and it was noticed that each variable correlates significantly with several other variables, which is also confirmed by the determinant of the correlation matrix, which is 0.000000000004266. The very low value of the determinant of the correlation matrix means that there are many significant correlations between the analyzed variables and there are probably factors that bind the given variables. Bartlett's sphericity test also confirms that the correlation matrix contains significant correlation coefficients, and the high value of the Kaiser-Mayer-Olkin measure (close to 1) provides a rationale for undertaking the factor analysis (Table 4).

In the first stage of the exploratory factor analysis, the number of dimensions (factors) formed by strongly related questions of the questionnaire was determined.

[3] In the literature, it is recommended that one suggest at least three to four variables for each potential factor and that the sample should consist of at least 200 observations (Rószkiewicz et al., 2013). Some authors believe that the number of observations should be even four or five times greater than the number of variables (Wieczorkowska, Wierzbiński, 2010). Both conditions in this study were met: eight factors were expected to be extracted with thirty-six variables, and the sample size of 511 companies far exceeded the recommended minimum.

Figure 1. **The Structure of Enterprises by the Area of Activity**



Source: author.

Table 3. **The Structure of Enterprises by Size, Type, and Area of Activity**

Indicator	Share (%)
Size	
Small enterprises	60.5
Medium enterprises	39.5
Type	
Manufacturing enterprises	34.6
Service enterprises	24.1
Enterprises combining manufacture and services	41.3
Area of activity	
Local market	35.6
National market	34.6
International market	29.7
Source: author.	

Table 4. **Determinant of the Correlation Matrix, KMO and Bartlett's Test**

Indicator	Value
Determinant of the correlation matrix	4.266E-012
KMO measure of sampling adequacy	0.958
Bartlett's sphericity test, Approximate Chi-Square	13097.637
df	378
Sig	0.000
Source: author.	

To extract the number of factors, the principal component as an extraction method allowing one to obtain such factors that explain the maximum percentage of variance of the initial variables was used. Apart from the maximum likelihood method, it is one of the most frequently recommended methods, which maximizes the connections between factors and variables and does not require that the analyzed data have a normal distribution (Brown, 2015). In order to further improve the fit of the factor structure to the output variables, Oblimin[4] with Kaiser Normalization rotation was used with a delta parameter equal to zero. In the case of the research problem presented in this paper, this would appear to be justified in view of the fact that factors are expected to be correlated as they relate to the measurement of the construct of foresight maturity. Using a factor loading matrix, ambiguous and insignificant variables were removed, namely variables that did not have factor loading with an absolute value greater than 0.4 (Lo, 2016). The variables that did not meet this criterion were variables number 9, 10, 12, 14, 15, 24, 25, and 36 (see Table 2). Using the exploratory factor analysis, eight factors were identified that influence the foresight maturity of SME enterprises as a set of highly valued, learned, repetitive organizational capabilities in anticipation of the future (Table 5). Given that these factors explain over 82.127% of the variance in the baseline variables (see Table 6), they enabled the grouping of observable variables. The correlation matrix confirms the assumption that the extracted dimensions are correlated with each other (Table 7). The interpretation of some of these correlations is represented at Table 8. Reliability analysis of the developed foresight maturity measurement scale (28 variables grouped into eight dimensions) was carried out using Cronbach's alpha values, which were counted separately for the subscales extracted in the factor analysis (Table 9).

Discussion of the Results

The foresight maturity level was calculated by averaging the respondents' results in individual survey questions. The level of indicators can take values from 1 to 7, according to the used Likert scale. Hence, the level of foresight maturity reaching values in the range <1.0-3.0) can be regarded as low, in the range <3.0-5.0) as medium, while in the range <5.0-7.0> as high (Leończuk, 2019; Ryciuk, 2016). In the case of the analyzed enterprises, the average level of foresight maturity of the analyzed SMEs is $x=3.29$ (with standard deviation $SD=1.21$), which, taking into account the seven-grade evaluation scale, can be considered as an average level. The median $Me=3.28$ (the middle line in Figure 6) also reaches a similar value.

[4] This rotation allows for the identification of correlations between factors and does not assume the zero correlation of the factors (Leończuk, 2019).

Table 5. **Capabilities in Anticipation of Future Gained by Companies**

Dimension (factor)	Description
F1: Involving stakeholders and building networks	Concerns the ability of the enterprise to involve employees in creating a vision and mission for the company. It also concerns the capability of the organization to involve external stakeholders (customers, representatives of industry organizations, and suppliers) in creating a vision of the company and product development
F2: Building supportive organizational culture	Refers to the recognition of the value of teamwork at the enterprise, to the creation of a climate conducive to innovation and the free and transparent flow of information at the company
F3: Scanning the micro- and macroenvironment of the company	Concerns the capabilities of the company to identify trends in the micro- and macroenvironment of the company affecting its development. It also comprises the capability of the company to identify signs of technological breakthrough in the sector as well as the ability to identify subtle signals of change that can influence the development of the industry in the future
F4: Using strong tie sources	Refers to the participation of the company in professional trade associations and prestigious scientific conferences as well as to the collection of information about patents by the enterprise
F5: Using weak tie sources	Refers to the activities undertaken by the company, such as reading specialist scientific journals to keep abreast of the latest trends affecting the development of the company's industry and searching the Internet and other media for trends shaping the development of the industry
F6: Creating aims for the company's development	Concerns the ability of the enterprise to create long-term objectives for the development of the organization that are consistent with the mission and vision for the development of the organization
F7: Thinking outside the box, reflectively and systemically	Refers to thinking about the products and services the company offers in an out-of-the-box way, concerns reflective and systemic thinking about the business activity
F8: Using foresight methods	Refers to the capability of the company to use roadmapping, mathematical methods of forecasting the future as well as the Delphi method to determine the vision of the company's development

Source: author.

Table 6. **The Results of Exploratory Factor Analysis**

Factor	Variable	Factor load
F1: Involving stakeholders and build networks	variable_20	0.763
	variable_17	0.719
	variable_19	0.714
	variable_18	0.687
	variable_16	0.675
	variable_13	0.536
F2: Building supportive organizational culture	variable_28	0.774
	variable_30	0.737
	variable_29	0.709
F3: Scanning the micro- and macroenvironment of the company	variable_1	0.802
	variable_3	0.774
	variable_4	0.734
	variable_2	0.622
	variable_5	0.573
F4: Using strong tie sources	variable_31	0.859
	variable_32	0.842
	variable_33	0.618
F5: Using weak tie sources	variable_34	0.870
	variable_35	0.833
F6: Creating aims for the company's development	variable_26	0.664
	variable_27	0.626
F7: Thinking outside the box, reflectively and systemically	variable_7	0.757
	variable_6	0.659
	variable_8	0.530
	variable_11	0.478
F8: Using foresight methods	variable_22	0.910
	variable_23	0.707
	variable_21	0.575

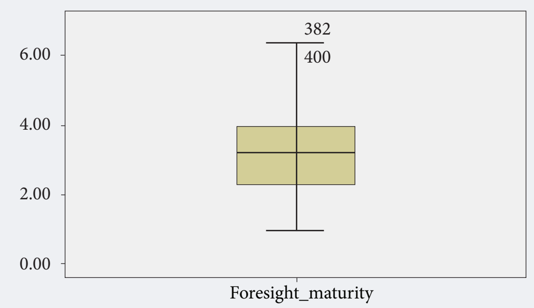
Note: Extraction method: Rotation method: Oblimin with Kaiser Normalization. Rotation converged in 12 iterations.

Source: author.

The values of the first and third quartile (upper and lower borders of the box) indicate that in the case of 50% of the surveyed companies, the level of the variable describing the average level of foresight maturity of small and medium-sized enterprises was between the values Q1=2.35 and Q3=4.00. Two outliers characterized by a high degree of maturity were also marked on the box plot with numbers 382 and 400. Both cases relate to medium, manufacturing, and international enterprises, one of which belongs to metal product manufacturing. In order to determine whether the level of foresight maturity differs between small and large companies, the Mann-Whitney test was conducted. The results of the test are presented in Table 10.

The significant value of the test statistic (p=0.0000) allows for concluding that the level of foresight maturity is statistically significant and different depending on the size of the enterprise (mean of 2.55 in small enterprises as compared to mean 4.24 in medium companies). In both groups, there is similar variation in

Figure 2. **Foresight Maturity Level of Polish SME Enterprises – Box Diagram**



Source: author.

Table 7. **Component Correlation Matrix**

Component	1	2	3	4	5	6	7	8
1	1.000	0.310	0.439	0.397	0.417	0.422	-0.354	**0.501**
2	0.310	1.000	0.332	0.269	0.323	0.224	**-0.508**	0.248
3	0.439	0.332	1.000	**0.494**	0.267	0.371	-0.360	**0.594**
4	0.397	0.269	**0.494**	1.000	0.279	0.271	-0.239	0.341
5	0.417	0.323	0.267	0.279	1.000	0.239	-0.279	0.304
6	0.422	0.224	0.371	0.271	0.239	1.000	-0.328	0.375
7	-0.354	**-0.508**	-0.360	-0.239	-0.279	-0.328	1.000	-0.280
8	**0.501**	0.248	**0.594**	0.341	0.304	0.375	-0.280	1.000

Source: author.

Table 8. **Interpretation of the Strongest Correlations between Dimensions**

Linked factors (codes)	Correlation coefficient	Explanation
F3 – F8	0.594	Selected foresight methods are widely used to scan the company's environment
F2 – F7	0.508	Supportive organizational culture allows one to think out of the box about products and services, positively influences the ability of the company to think in a reflective way as well as stimulates the capability to think about the company in a systemic way
F1 – F8	0.501	Capability to use foresight and forecasting methods as a result of socializing the process of building the enterprise vision requires the capability to use foresight and forecasting methods
F3 – F4	0.494	The dimension F3 refers to the general capabilities of companies in scanning the micro- and macroenvironment, while the dimension F4 refers to specific scanning activities (participation in the activities of industry associations, prestigious scientific conferences, collecting information on patents)

Note: See Tables 5 and 6 for the description of dimension codes.
Source: author.

Table 9. **Cronbach's Alpha Values for Foresight Maturity in SME Dimensions**

Factor	Variable numbers	Cronbach's alpha
F1	13, 16, 17, 18, 19, 20	0.943
F2	28, 29, 30	0.922
F3	1, 2, 3, 4, 5	0.927
F4	31, 32, 33	0.885
F5	34, 35	0.831
F6	26, 27	0.859
F7	6, 7, 8, 11	0.883
F8	21, 22, 23	0.881

Note: See Tables 5 and 6 for the description of dimension codes.
Source: author.

values, as evidenced by the standard deviation values at the level of 0.9 for small enterprises and 0.97 for medium enterprises. The median value is similar in small and medium enterprises, yet the difference between the median values is statistically significant.

It was also verified whether the mean values of all eight identified dimensions of foresight maturity differed in a statistically significant way depending on the size of the enterprise. The differences in assessments are presented in Figure 3. Based on the analysis of the graph, it can be noted that the highest average scores in medium companies were obtained for *The capability to think outside the box, reflectively and systematically* and for *The capability to create aims of the company's development*. Slightly lower, but still highly rated are the dimensions: *The capability to involve stakeholders and build networks and the capability to scan the micro- and macroenvironment of the company*. These results are not surprising as the capabilities mentioned above are fundamental for foresight activities run at the enterprises (Sarpong, Maclean, 2011; von der Gracht et al., 2010, Saprong, Maclean, 2016; Weissenberger-Eibl 2019; Ruff, 2015; Vecchiato, 2015). The lowest rating among medium-sized enterprises was given to *The capability to use strong tie sources* which might indicate that the medium-sized companies either are unlikely to have the necessary human and financial resources or do not pay enough attention to the participation in professional trade associations and in prestigious scientific conferences nor do they pay enough attention to the collection of information about patents. Among small enterprises, *The capability to think outside the box, reflectively and systematically* was also rated highest, in turn, the lowest rated was *The ability to build a supportive organizational culture*. This may stem from the fact that small businesses, mainly due to their involvement in day-to-day and limited resources, pay little attention to building supportive organizational culture, i.e., to the recognition of the value of teamwork at the enterprise, to the creation of a climate conducive to innovation, and the free and transparent flow of information at the enterprise. The significant value of the test statistic (p=0.0000) for each of the identi-

Table 10. Mann-Whitney Test and Basic Statistics

Dependent variable — foresight maturity	Independent variable (grouping): size of the company	
	Small enterprises (0-49)	Medium enterprises (50-249)
Number of enterprises N (total = 511)	309	202
Mean rank	178.82	374.06
Sum of ranks	55255.50	75560.50
Mean	2.66	4.25
Standard deviation	0.9	0.97
Median	2.59	2.58

Mann-Whitney U	7360.500
Wilcoxon W	55255.500
Z	-14.617
Significance (2-tailed)	0.0000

Source: author.

fied foresight dimensions makes it possible to state that the mean values of foresight dimension are statistically significant and different (Table 11).

Furthermore, when analyzing the means and medians for the presented dimensions, it can be seen that these values do not differ much from each other, which means that a mean is an appropriate measure for assessing the average level of foresight maturity dimensions at companies (Table 12). Still, when analyzing the coefficient of variation, one can notice higher values for particular dimensions at small enterprises. This means that the respondents here were less unanimous in their assessments. On the one hand, this may be due to the fact that small enterprises do not have sufficient resources to implement future-oriented activities, on the other, it could be that within this group of enterprises, however, there are companies that rate their foresight capabilities highly.

Table 11. Mann-Whitney Test for Each Foresight Dimension (grouping variable: size of the company)

Dimension code	Mann-Whitney U	Wilcoxon W	Z	Significance (2-tailed)
F1	10770.500	58665.500	-12.535	**0.000**
F2	8913.500	56808.500	-13.971	**0.000**
F3	6634.000	54529.000	-15.078	**0.000**
F4	12535.000	60430.00	-11.512	**0.000**
F5	19270.500	67165.500	-7.347	**0.000**
F6	14186.500	62081.500	-10.486	**0.000**
F7	13981.000	61876.000	- 10.574	**0.000**
F8	11885.000	59780.00	-11.881	**0.000**

Source: author.

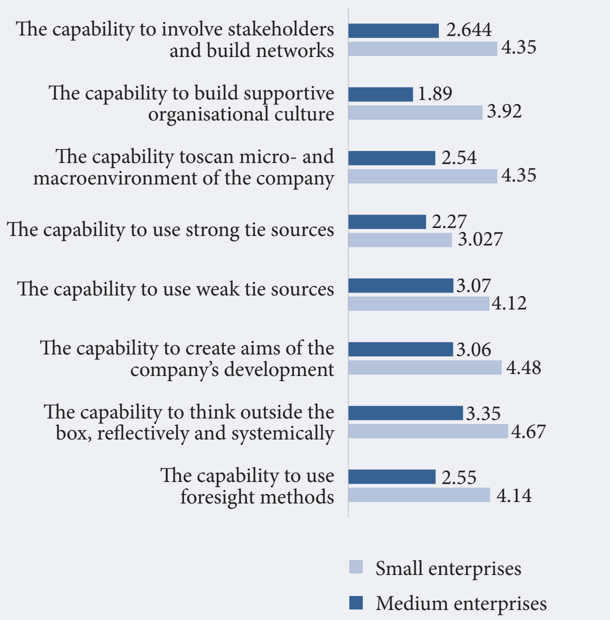
Table 12. Foresight Dimensions – Basic Statistics

Foresight maturity dimension	Mean	Median	Standard deviation	Coefficient of variation
F1 (small)	2.644	2.5	1.28	**48**
F1 (medium)	4.35	4.5	1.2	28
F2 (small)	1.89	1	1.18	**62**
F2 (medium)	3.92	4	1.38	35
F3 (small)	2.54	2.4	1	**39**
F3 (medium)	4.35	4.4	1	23
F4 (small)	2.27	2	1.21	**53**
F4 (medium)	3.93	3.83	1.52	39
F5 (small)	3.027	3	1.6	**53**
F5 (medium)	4.12	4	1.61	39
F6 (small)	3.06	3	1.42	**46**
F6 (medium)	4.48	4.5	1.23	27
F7 (small)	3.35	3.25	1.29	**39**
F7 (medium)	4.67	4.75	1.08	23
F8 (small)	2.55	2.33	1.09	**43**
F8 (medium)	4.14	4	1.38	33

Note: small = small enterprises, medium = medium enterprises. See Tables 5 and 6 for the description of dimension codes.

Source: author.

Figure 3. Differences in Assessments of the Dimensions of Foresight Maturity at Small and Medium-Sized Enterprises



Source: author.

Table 13. **Differences in the Level of Foresight Maturity by Type and Area of Company Activity**

Dependent variable: foresight maturity	N	Mean	Standard deviation	Median	Mean rank	Kruskal-Wallis test results
Independent grouping variable: type of company						
production	177	3.8	1.41	3.86	311.05	Chi^2=39.039, df=2, p=0.000
services	123	3.07	0.98	3.2	214.32	
production and services	211	2.95	0.98	2.96	234.12	
Independent grouping variable: area of activity						
local	182	2.56	0.9	3.33	165.57	Chi^2=134.897 df=2 p=0.000
national	177	3.36	1.09	3.32	265.49	
international	152	4.1	1.12	4.01	353.22	

Source: author.

Differences in the level of foresight maturity depending on the type of company and its area of activity were also examined. For this purpose, the Kruskal-Wallis test[5] was used, which is a non-parametric equivalent of the one-way analysis of variance that assesses whether independent samples come from the same population or from a population with the same median (Stanisz, 2006). The results of the Kruskal-Wallis test (test probability level not exceeding 0.05) indicate that the level of the foresight maturity of small and medium enterprises depends on the type and area of activity of the enterprise. Analyzing the data in Table 13, it may be noticed that the lowest level of foresight maturity is characteristic of production and service enterprises (mean=2.95) and those operating on the local market (mean=2.56), whereas the highest level is characteristic of production enterprises (mean=3.8) and those operating on the international market (mean=4.1). There is also a rational justification for this situation. Manufacturing companies experience frequent changes in the technological environment, hence undertaking activities in the area of future-preparedness is justified. Similarly, companies operating on the international market, due to the unpredictability of the global environment, must undertake more actions in the area of foresight than companies operating on the local and domestic markets.

Conclusions

The presented quantitative analysis of the foresight maturity of enterprises complements the qualitative research carried out by Grim and Rohrbeck in the field of identifying the factors that create the dimensions of foresight maturity for enterprises. The exploratory factor analysis carried out allowed the author to further refine the definition of the foresight maturity at small and medium-sized enterprises. The analyses made it possible to identify 28 factors of the foresight maturity at small and medium enterprises grouped into eight dimensions. SME companies that are interested in increasing their foresight maturity should implement in their daily practice the capabilities related to involving stakeholders in creating the vision and mission of the company, building a supportive organizational culture, scanning the micro- and macroenvironment of the enterprise. The equally valuable components are the capabilities to work with weak tie sources of information, to set realistic goals, and to think outside the box, reflectively and systemically.

In general, the level of foresight maturity of Polish manufacturing SMEs is assessed as medium, but the results of non-parametric tests indicate its dependence on the size, type, and geography of companies' activities. The most mature are medium-sized manufacturing enterprises operating on the international market. In addition, maturity indicators differ significantly between small and medium-sized entities. The impact of these factors on corporate innovation activity is assessed. Measures are proposed to develop appropriate potential to increase competitiveness in an unpredictable and multidimensional environment.

The main limitations of the present research are related to the use of a Likert scale questionnaire, which involves the risk of subjective answers from respondents due to insufficient familiarity with such basic corporate foresight terms as weak signals or wild cards, or their incorrect interpretation. Further directions of the research are to cover countries with other levels of economic development and to compare levels of foresight maturity. The author also envisages extending the research with qualitative research in the form of individual interviews carried out at small and medium-sized enterprises, which will allow for more generalized conclusions and increase the reliability of the research process.

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[5] The Kruskal-Wallis test is a non-parametric equivalent of the one-way analysis of variance that assesses whether independent samples come from the same population or from a population with the same median (Stanisz, 2006).

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