FORESIGHT

AND STI GOVERNANCE

JOURNAL OF THE NATIONAL RESEARCH UNIVERSITY HIGHER SCHOOL OF ECONOMICS

ISSN 2500-2597

2021
Vol.15 No 3

IN THIS ISSUE

ABOUT THE JOURNAL

Foresight and STI Governance is an international interdisciplinary peer-reviewed open-access journal. It publishes original research articles, offering new theoretical insights and practice-oriented knowledge in important areas of strategic planning and the creation of science, technology, and innovation (STI) policy, and it examines possible and alternative futures in all human endeavors in order to make such insights available to the right person at the right time to ensure the right decision.

The journal acts as a scientific forum, contributing to the interaction between researchers, policy makers, and other actors involved in innovation processes. It encompasses all facets of STI policy and the creation of technological, managerial, product, and social innovations. *Foresight and STI Governance* welcomes works from scholars based in all parts of the world.

Topics covered include:

- Foresight methodologies and best practices;
- Long-term socioeconomic priorities for strategic planning and policy making;
- Innovative strategies at the national, regional, sectoral, and corporate levels;
- The development of National Innovation Systems;
- The exploration of the innovation lifecycle from idea to market;
- Technological trends, breakthroughs, and grand challenges;
- Technological change and its implications for economy, policy-making, and society;
- Corporate innovation management;
- Human capital in STI;

and many others.

The target audience of the journal comprises research scholars, university professors, post-graduates, policy-makers, business people, the expert community, undergraduates, and others who are interested in S&T and innovation analyses, foresight studies, and policy issues.

Foresight and STI Governance is published quarterly and distributed worldwide. It is an open-access electronic journal and is available online for free via:
https://foresight-journal.hse.ru/en/

The journal is included into the 1st quartile (Q1) of the Scopus Cite Score Rank in the fields:

- **Decision Sciences miscellaneous);**
- **Economics, Econometrics and Finance (miscellaneous);**
- **Social Sciences (miscellaneous);**
- **Social Sciences: Development;**
- **Statistics, Probability and Uncertainty**

INDEXING AND ABSTRACTING

Web of Science Core Collection Emerging Sources Citation Index
Scopus
RePEc Research Papers in Economics
SSRN
ProQuest
Genamics JournalSeek
EBSCO
Academic Search Premier
OAJI.net Open Academic Journals Index
EconStor
DOAJ Directory of Open Access Journals

FORESIGHT AND STI GOVERNANCE

National Research University
Higher School of Economics

Institute for Statistical Studies
and Economics of Knowledge

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

http://foresight-journal.hse.ru/en/

Periodicity — quarterly

ISSN 2500-2597
ISSN 2312-9972 (online)
ISSN 1995-459X (Russian print version)

Publisher:
National Research University
Higher School of Economics

CONTENTS

Vol. 15. No. 3

STRATEGIES

INNOVATION

MASTER CLASS

New Strategic Approaches to Gaining from Emerging Advanced Manufacturing Markets

Yuri Simachev*

Director and Professor, yusimachev@hse.ru

Anna Fedyunina

Senior Research Fellow, afedyunina@hse.ru

Maksim Yurevich

Researcher, mayurevich@hse.ru

Mikhail Kuzyk

Deputy Director, mkuzyk@hse.ru

Nikolai Gorodny

Research Intern, na.gorodnyi@hse.ru

Center for Industrial Policy Studies, National Research University Higher School of Economics, 11 Pokrovsky Blvd, Moscow, 101000

Abstract

Advanced Manufacturing (AM) markets are a major factor of modern global growth which to a large extent determines countries' competitiveness. This article discusses the structure and dynamics of the development of advanced manufacturing markets, as well as the specifics of the policies of the countries strengthening their positions in these markets, based on the analysis of international trade in products using advanced manufacturing technologies.

The study shows that in the last decade there has been a noticeable structural shift in AM: Industry 4.0 is growing faster, and the key growth driver is the biotechnology market. Large innovative economies — USA, France, Japan — are being displaced from AM markets, while new industrialized countries — Korea, Taiwan, and fast-growing China — are becoming leaders. The new AM markets — Industry 4.0 — are characterized by a high concentration of knowledge in universities combined with a high activity of start-ups, while the relatively traditional AM markets — Industry 3.0 — show a higher concentration of production. The position of countries in Industry 4.0 markets is significantly related to the monopoly of new knowledge and the opportunities for its rapid commercialization in start-ups, while in Industry 3.0 markets the processes of leading firms' specialization and use of scale are already more significant, and the research environment is becoming more competitive.

Strengthening and/or optimizing the positions on AM markets becomes the most important challenge for modern industrial policy. On the one hand, the choice of target markets determines significant alternatives in industrial policy (e.g., betting on the creation of new knowledge or on the spread of advanced technology), on the other hand, the sensitivity of progress to the complementarity of changes forms the demand for a comprehensive industrial policy, combining elements of science and technology, innovation, investment, and human capital development policies.

Keywords: advanced manufacturing; strategies; innovation; new technologies; biotechnology; Industry 4.0; international trade; industrial policy

Citation: Simachev Y., Fedyunina A., Yurevich M., Kuzyk M., Gorodny N. (2021) New Strategic Approaches to Gaining from Emerging Advanced Manufacturing Markets. *Foresight and STI Governance*, 15(3), 6–21. DOI: 10.17323/2500-2597.2021.3.6.21

* Yury Simachev is also Director for Economic Policy at the HSE.

Introduction

Advanced technologies are changing the global manufacturing landscape. Many developing countries are losing their main advantage in the form of cheap labor under the pressure of automation [World Bank, 2016]. Developed economies are becoming more independent due to the reduced costs of certain processes [*Hallward-Driemeier, Nayyar,* 2018; UNIDO, 2020; *Rodrik,* 2018].

It is widely believed that advanced manufacturing (AM) is concentrated in just a few countries, while for others, entry onto relevant markets is closed or limited [*Kim, Qureshi,* 2020]. No tools are currently available to assess individual economies' competitiveness and positions on AM markets. Patent data is usually used to analyze the dissemination of advanced manufacturing and fourth industrial revolution technologies (AMTs and Industry 4.0, respectively) [*Kim, Bae,* 2017; *Fujii, Managi,* 2018; *Ardito et al.,* 2018]. Such studies reflect the rate of new technology development, but the scale of their practical application is measured only to a limited extent [*Castelo-Branco et al.,* 2019]. Practically no international comparisons have been made [*Horváth, Szabó,* 2019; *Fulton, Hon,* 2010]. Readiness for advanced manufacturing is often assessed via innovation development indices [*Naudé et al.,* 2019; *Simachev et al.,* 2020]. There is no single, generally accepted definition of AM, though its key characteristics include the ability to customize and scale production in the process of improving technologies. Based on the definitions proposed in [STPI, 2010; *Shipp et al.,* 2012], AM comprises traditional and high-tech industries which upgrade existing and create new materials, products, and processes. This is achieved by integrating technology with a highly productive workforce and innovative business models. The goal of this paper is to identify the structural features of AM markets and assess their importance for specific national economies through the prism of international trade in high-technology products.

Methodology

Approaches to assessing international trade in AM products command researchers' and policymakers' interest, but various countries pursue very different goals in this area. In China such analysis is primarily conducted to design national industrial strategy and covers products manufactured using not only AMTs but also other technologies. In the United States, this process is not directly linked to accomplishing strategic goals but is applied only for the statistical monitoring of international trade [*Ferrantino et al.,* 2010].

Since AMTs are used in traditional and new industries alike, it is rather difficult to draft a precise list of them. A generally accepted view is that the AM definition should be dynamic and its technological "frontier" should be flexible and mobile.[1] This assumption is in line with the approach of the US Census Bureau which has developed the first AMT product classification to measure international trade in 1989. It has been regularly revised to reflect the changes in the Harmonized System (HS)[2] codes on the basis of expert evaluation.

The methodology for defining AM markets applied in this study is based on combining the US Census Bureau approach[3] with the one presented in [*Foster-McGregor et al.,* 2019]; the latter work identified four types of Industry 4.0 technologies: bio-, CAD/CAM, additive technologies, and robotics. We used COMTRADE data[4] for 2002-2018 (six-digit codes-based product classifications HS 2002 and HS 2017). The HS classification was revised in 2002, 2007, 2012, and 2017. New codes were added to take into account the growing product range. However, the updated HS version does not allow for making retrospective assessments, i.e., it does not allow one to analyze data over long periods of time. Therefore, the HS 2017 classification was used to describe the 2017-2018 markets,[5] while comparing it with the HS 2002 version allowed the authors to reveal long-term shifts in international trade. Eleven global AMT product markets were analyzed and divided into three groups[6] (Table 1, Figure 1).

Structural Features of Global AM Markets

In 2018, AM markets amounted to 21.4% of total global exports, which is slightly higher than in

[1] https://www.nist.gov/system/files/documents/2017/05/09/advanced-manuf-papers.pdf, accessed on 27.12.2020.

[2] https://www. trade.gov/harmonised-system-hs-codes, accessed on 19.11.2020.

[3] https://www.census.gov/manufacturing/m3, accessed on 04.12.2020.

[4] https://comtrade.un.org/, accessed on 08.12.2020.

[5] Analyzing the value of the world's AM markets on the basis of the HS 2017 classification allows one to refine the estimates obtained using the HS 2002 nomenclature, including the overall AM market size: for HS 2002 codes, the market was 5.965 trillion USD, and for HS 2017 8.56 trillion USD in 2018 (a 43.5% growth). However, this more precise estimate did not reveal significant shifts in the AM market structure. E.g., the share of ICT in the aggregate AM market according to the HS 2002 nomenclature is 30.1%, and according to HS 2017 it is 34.1%, life sciences 20.7% and 14.8%, aerospace industry 12.4% and 8.5%. The most significant discrepancy is in electronics (11.2% vs 24.2%). The structural shifts in countries' positions are less significant: in 2018 China's share amounted to 15.9% of the world's total exports of AM products according to HS 2002, and 19.4% according to HS 2017. Germany's share was 11.3% and 8.8%, the US's 9.5% and 8.8%, respectively.

[6] The product groups under consideration can belong to several markets at the same time and the US Census Bureau's approach does take this into account. E.g., according to the US Census Bureau classification, optical media for sound recording should be attributed to three AM markets: optoelectronics, electronics, and ICT. According to the same nomenclature, electrodiagnostic equipment simultaneously belongs on the life sciences and electronics markets. To avoid a double count of the same commodities on different AM markets when analyzing the aggregate global market, the items were assigned to a single market by expert evaluation.

the early 2000s (18.2%). The share of Industry 4.0 products in total exports has marginally increased, from 5.1% to 5.8% (Figure 2). The growth rate of AM products' share in global trade over the past two decades was lower than expected. As will be shown below, significant structural changes took place on the markets, which turned out to be vulnerable to global economic crisis. The double-digit growth rates of almost all segments observed in 2002-2007 in the post-crisis period were replaced by negative or weakly positive ones (Table 2). The slower growth is largely due to increased tension in international economic relations, the aggravation of "trade wars", and the efforts to strengthen national technological security.

In 2013-2018, the Industry 4.0 segment rapidly grew, while the growth of Industry 3.0 product markets slowed down due to saturation. Biotechnology is the most rapidly growing area (these markets' share grew from 1.8% in 2002 to 6.6% in 2018). This growth that is unrelated to the state of the global economy probably can be explained by the specific features of the dominant products, i.e., medical supplies of biological origin. The reduced growth of the nuclear technology market is largely due to the accident in Japan in 2011 and the transition to alternative energy sources primarily in the leading countries [*Gasparatos,* 2017]. The Industry 3.0 segment accounts for slightly less than half of the total AM market (Figure 3). The small shares of armaments and especially nuclear energy are due to the domestic consumption of relevant products in the producer countries and, consequently, their lower involvement in international trade.

Countries' Positions on AM Markets

At the end of 2018, China was the clear leader on the aggregate AM product market, mainly due to ICT services (67% of relevant product exports). Germany and the US were slightly behind, with more diversified markets. In Germany, the life sciences segment accounts for 24%, ICT for 17%, and electronics for 14%. In the United States, ICT services amount to 29%, life sciences to 21%, and electronics to 20%. Next comes Hong Kong, which specializes in ICT services and electronics (Figure 4).

Leaders on the aggregate global AM market also hold leading positions in most of its segments. China is among the top five countries on seven markets, the US and Germany on ten (the only "lost" market for both these countries is electronics, which is the second largest). Many smaller economies including Ireland, Belgium, Spain, Singapore, and Vietnam dominate certain markets; notably, their positions are not directly related to their development level or their scale of economic activities (Table 3).

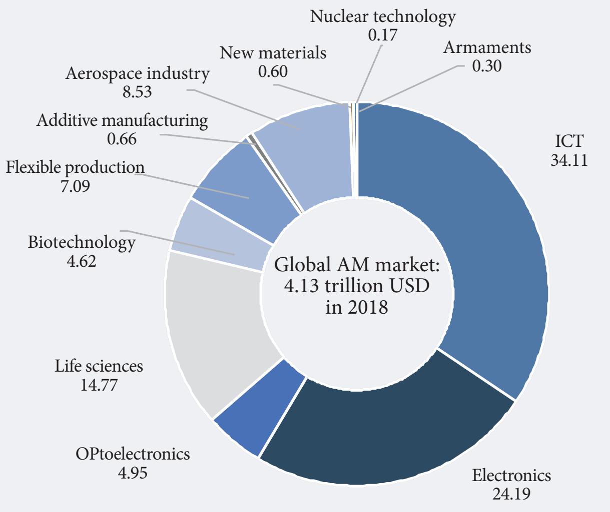
Russia's share on global AM markets does not exceed 0.6%; the same is true for the aggregate hi-tech product market (no more than 0.5%), with the exception of nuclear technology (16.7% of the global market) and armaments (1.2%). The country's positions are especially strong in the electronics, optoelectronics, ICT services, and life sciences segments. Biotechnology products have the smallest share. In 2002-2018 the technological "portfolio" in the biotechnology and life sciences segment grew (the gap with Germany, the US, Korea, and China has narrowed). Thus, Russia's relatively low "involvement" on global AM markets is due not to a narrow product specialization but rather to the low competitiveness of its products. China has a comparative advantage (according to the Balassa Index[7]) in antioxidants (life sciences) and ICT products (computers, video recorders, monitors, and mobile phones). Germany dominates the flexible manufacturing systems market (including hydraulic and pneumatic devices). Russia's positions are strongest in the production of jet engines (aerospace), nuclear reactors and components, and heat dissipating elements (nuclear technology). China's leadership is due to the general redistribution of the balance of power on the global AMT product markets. India and Vietnam are getting closer to the leader. Mexico has been making steady progress since 2010, while the US and a number of European countries have reached a "plateau" (Table 4).

Changing the balance of power on the AM markets has led to traditional innovation leaders (the US, France, and Japan) being pushed aside by China, Korea, Taiwan, Singapore, the Philippines, India, Mexico, and Vietnam. This trend did not affect Germany, which is still advancing in the markets under consideration. The decline in other leading countries' market shares is due not only to the pressure from new players, but also to their switching to more promising areas such as Industry 4.0 (e.g., Germany, the UK, and Ireland). Ireland's success in the aerospace sector is based on the establishment of a global aircraft leasing hub [*Osborne-Kinch,* 2017] and in biotechnology – on attracting investment and building advanced production infrastructure. However, the country's position in life sciences has weakened due to the growing competition from China and India. The UK's falling into the "outsiders" group on all five markets was also caused by the strengthening of the Asian countries.

---

[7] The definition of the Revealed Comparative Advantage Index (RCA) in [*Balassa,* 1965] was used in this study. The index is calculated for each AM market as the ratio of its share in the country's total AM product exports to the share in total global exports of AM products. If RCA>1, the country is generally believed to have a revealed comparative advantage in the export of relevant products.

Figure 1. **AMT Product Markets and their Share on the Aggregate AM Market (%)**



Sources: authors' calculations based on US Census Bureau data for 2020, [*Schwab,* 2014], COMTRADE data for 2018, and HS 2017 classification.

The growing share on the aerospace market is due to the increased supply of aircraft components, primarily engines (Figure 5).

The changes in the global AM markets' "design" among other things have been caused by the implementation of industrial policies aimed at increasing competitiveness and accelerating growth through structural reforms. However, countries' priorities and implementation methods vary significantly. Industry 4.0 radically changes the understanding of industrial policy vector and stakeholders [*Reischauer,* 2018]. Germany, China, and the US are striving to maintain leadership by increasing value added in the manufacturing industry. France and Japan localize production, increase its sustainability, and reduce the negative effects of high labor costs. France aims to modernize its manufacturing basis and retain AM leadership, provided it can contain labor costs growth and related social factors [*Blanchet et al.,* 2016]. Russia's industrial policy is mostly vertical in nature, providing selective support and "appointing champions" — industries

Table 1. **Classification of AM Markets**

Group	Number of markets	Composition	Share in aggregate AM market (%)
Industry 3.0	3	Electronics, optoelectronics, ICT	63.2
Industry 4.0	4	Additive manufacturing, biotechnology, life sciences, flexible production (including robotics)	27.2
Other*	4	New materials, aerospace, nuclear technologies, armaments	9.6

* Products not directly related to Industry 3.0 and 4.0. COMTRADE data includes only public information on international trade in armaments. Thus the above estimates do not reflect this market's actual size. However, using this approach makes sense for two reasons. Other available data allows to estimate the overall arms market size without breaking it down into product types (e.g. the SIPRI Arms Transfers Database project). For us, it's important to consider structural shifts not only between markets but also within them, at the level of specific product groups. In line with the adopted approach, the arms market comprises not only armaments and their parts, but also prismatic infrared binoculars, optical telescopes, periscopes, navigation logbooks, and depth sounding equipment..

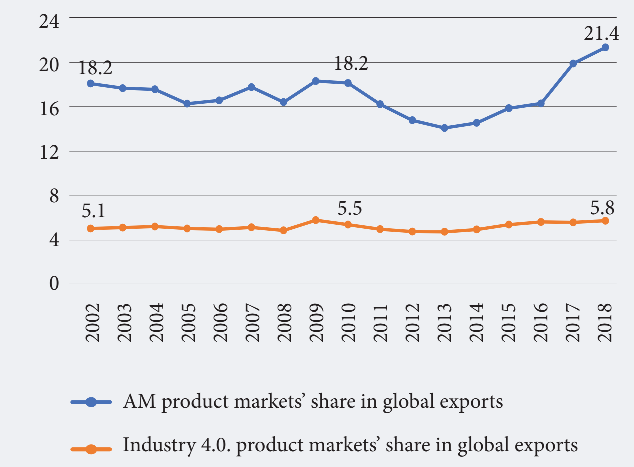
Source: authors.

Table 2. **Average Annual Growth of AM Product Markets and Global Product Exports (in current prices), by Period (%)**

Group	AMT product market	Total for 2002-2018	Out of that during:		
			2002-2007	2008-2013	2014-2018
Industry 3.0	Electronics	5.2	28.2	-11.0	1.4
	Optoelectronics	5.5	10.1	8.3	-3.3
	ICT	5.0	14.9	1.8	-1.2
Industry 4.0	Additive manufacturing	5.7	14.0	1.6	0.8
	Biotechnology	15.3	24.4	12.9	8.3
	Life sciences	6.9	16.5	2.4	1.6
	Flexible production	8.5	20.1	-0.9	8.1
Other AM markets	New materials	8.7	20.9	-2.7	8.5
	Aerospace	4.9	10.5	-0.2	2.6
	Nuclear technology	1.3	16.3	-4.5	-5.9
	Armaments	6.7	9.8	5.6	4.2
For reference	All AM markets	6.1	17.0	0.2	1.4
	Global product exports	7.1	16.6	3.2	0.7

Sources: authors' calculations based on COMTRADE data and HS 2002 classification.

Figure 2. **Shares of AM and Industry 4.0 Markets in Total Product Exports** (%)

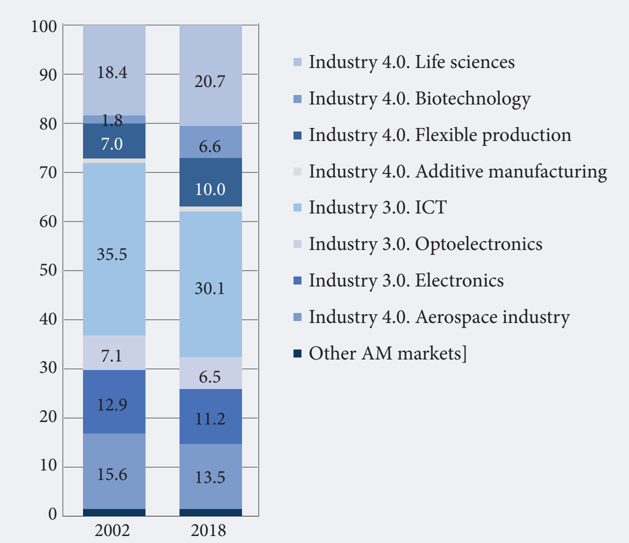


Sources: authors' calculations based on COMTRADE data and HS 2002 classification.

and individual companies [*Simachev et al.*, 2020; HSE, 2018]. As a consequence, public support is typically provided to large players in traditional sectors. Policy evaluation and adjustment as well as abandoning ineffective projects remain rare and limited. Policy areas, tools, and initiatives aimed at compensating for unfavorable changes or encouraging catching-up development of industries and companies dominate, while attempts to adopt development models which would allow for taking the lead remain rare and fragmentary [*Simachev et al.*, 2018]. Countries' positions on export and import markets are generally similar. The five largest importers are the US (15.9% of the total in 2018), China (15.6%), Hong Kong (8.3%), Germany (6.4%), and Japan (4.0%) (Figure 6).

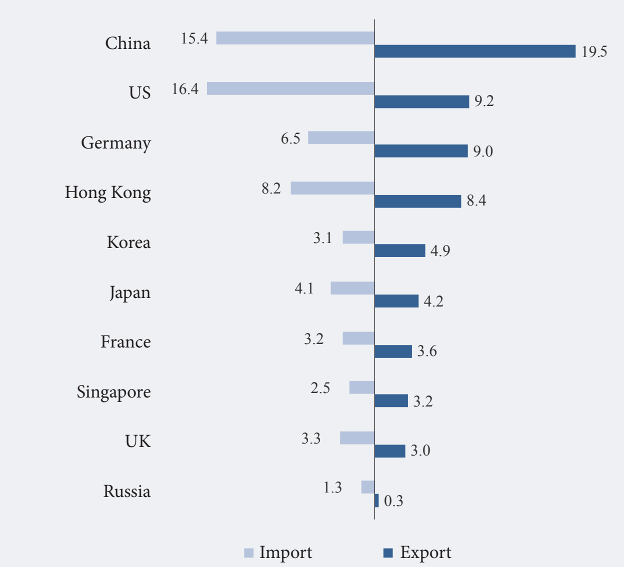
In 2002-2018 China gradually pushed the US out in the imports of AM products. Russia and Vietnam stand out among other countries which have noticeably increased their share on the aggregate import market. The US currently leads in nine out of eleven AM import markets; the exceptions are electronics and flexible production systems where China dominates and the US comes in second. China is not among the top five biotechnology and armament importers. Germany leads in eight segments. Russia is not one of the top five importers in any segment, but still has larger import shares than export ones (except for nuclear technologies and armaments). In per employee terms, the country's weight on the export and import AMT product markets is almost the same. Globally, AMT product export unit costs explain up to 93.5% of the changes in the same indicator for imports (Figure 6). This means that countries actively manufacturing AMT products for foreign markets are also major consumers of such goods, using them both as intermediate products for export (including in the scope of global value chains) and as finished end products (taking into account the relative specialization in specific AM markets). The group of countries whose per employee AMT product exports and imports exceed 10,000 USD mainly comprises developed economies or those approaching

Figure 3. **Global AM market Structure** (%)



Sources: authors' calculations based on COMTRADE data and HS 2002 classification.

Figure 4. **Selected Countries' Shares in Total Exports of AM Products: 2018** (%)



Sources: authors' calculations based on COMTRADE data and HS 2017 classification.

Table 3. **Leading Exporters of AM Products: 2018** (%)

Group	AM market	1st place	2nd place	3rd place	4th place	5th place	For reference: Russia's share
Industry 3.0	Electronics	Hong Kong (15.9)	China (14.3)	Korea (12.4)	Taiwan (10.8)	Singapore (9.5)	0.1
	Optoelectronics	China (24.1)	Germany (10.7)	US (8.4)	Japan (5.5)	Korea (5)	0.6
	ICT	China (37.8)	Hong Kong (11.2)	US (7.5)	Vietnam (4.9)	Germany (4.4)	0.2
Industry 4.0	Additive manufacturing	Germany (23.4)	China (15.9)	Japan (9.6)	Italy (9)	US (6.1)	0.1
	Biotechnology	Switzerland (16.5)	Ireland (16.4)	Germany (15.8)	US (13)	Belgium (9.4)	0.1
	Life sciences	Germany (14.5)	US (12.3)	Switzerland (10.6)	Ireland (8.2)	Belgium (6.5)	0.1
	Flexible production	Japan (15.5)	Germany (15.3)	US (12.1)	China (8.8)	Korea (6.5)	0.3
Other AM markets	New materials	China (22.4)	Japan (18.2)	US (12.3)	Germany (6.8)	Korea (6.4)	0.6
	Aerospace	France (19.6)	Germany (16.6)	UK (13)	US (6)	Singapore (5.9)	1.2
	Nuclear technology	Russia (16.7)	Germany (16.2)	France (12.2)	US (11.7)	Netherlands (11)	-
	Armaments	US (43.4)	China (5.1)	Korea (5.1)	Germany (4.4)	Spain (3.5)	1.2

Sources: authors' calculations based on COMTRADE data and HS 2017 classification.

this level: the EU member states, the US, Canada, Japan, the UAE, Malaysia, South Korea, and Israel.

Factors Affecting Countries' Leadership on AM Markets

Countries' positions in AMT product trade correspond to their global leading university rankings [*Tuesta et al.,* 2019; *Marginson,* 2007; *Marginson, van der Wende,* 2007]. A correlation between the number of such universities and AMT product exports was established in life sciences, biotechnology, ICT, electronics and optoelectronics, additive technologies, flexible production, and aerospace segments.

A group of leading countries stands out, with at least five universities included on the top 500 list (except for Israel which has four), while their AMT exports amount to at least 2% of GDP. For the majority of them, centuries-old academic traditions paved the way to leadership in educational rankings (the UK, Germany, China, France, Italy, Belgium, Switzerland, and the Netherlands). A relatively recent addition is South Korea. Another cohort is "promising AMT exporters": Australia, Russia, India, Argentina, Brazil, and New Zealand. The ratio of relevant product exports to GDP does not exceed 2% there, and these countries also have at least five universities among the world's top 500.

The distribution of knowledge production centers (universities included in global subject-specific

Table 4. **Selected Countries' Shares in Global Imports of Advanced AM Products (%)***

Country	2002	2006	2010	2014	2018
China	6.2	12.4	15.5	16.9	15.9
US	17.4	14.5	10.4	10.5	9.5
Germany	9.6	10.5	9.5	10.6	11.3
Japan	8.9	7.4	6.7	4.7	4.6
Hong Kong	4.4	5.4	6.3	5.0	4.8
Brazil	0.4	0.3	0.3	0.3	0.3
Russia	0.4	0.2	0.2	0.4	0.3
India	n/a	0.2	0.4	0.9	0.9
South Africa	0.1	0.1	0.1	0.1	0.1
Korea	3.1	3.1	3.6	2.5	3.1
Mexico	2.9	1.7	1.5	2.2	2.8
Taiwan	n/a	2.7	3.9	2.4	2.4
Philippines	n/a	n/a	0.4	0.6	0.6
Turkey	0.1	0.1	0.1	0.1	0.2
Vietnam	n/a	0.1	0.1	0.5	0.8
Malaysia	3.1	2.7	2.6	1.8	2.0
Nigeria	n/a	0.0	0.0	0.0	0.0
Norway	0.3	0.3	0.3	0.3	0.2
Canada	2.0	1.6	1.3	1.4	1.4
Egypt	n/a	n/a	0.0	0.0	0.0

*To analyse the changes in the aggregate AM market situation, we selected countries at different stages of economic development according to the World Bank classification, including: developed, newly industrialised, and emerging ones, and the BRICS group.

Sources: authors' calculations based on COMTRADE data and HS 2002 classification.

rankings) in AM markets is consistent with the geography of innovative start-up creation. According to Crunchbase, nearly 40% of AMT companies are established in the US,[8] followed by the UK (5.5%), China (5.2%), Germany (4.1%), and Canada (3.6%).

In the Czech Republic, Slovakia, Romania, Hungary, Ukraine, Hong Kong, and Taiwan, most of such companies specialize in electronics. Biotechnological firms are mainly located in the US, Canada, Australia, Israel, the UK, Ireland, and Switzerland. Russia and India have numerous robotics start-ups, but the level of job robotization is negligible. Start-up distribution by industry in individual countries is close to the world average. With the exceptions of Belgium and Switzerland, the ICT sector is dominated by developing countries (Malaysia, Indonesia, Brazil, South Africa, the UAE); the share of start-ups there is more than double the global average. The main features of AM markets are presented in Table 5.

The Industry 4.0 and electronics markets are extremely competitive and have a high concentration of knowledge production (as illustrated by the number of leading universities). The emerging nature of Industry 4.0 markets is indicated by their concentration in just a few countries due to the unique nature and limited availability of knowledge upon which the relevant technologies are based. The associated Industry 3.0 electronics market is gaining new momentum. These markets have not yet reached the scale which would lead to emergence of global manufacturing hubs (such as in optoelectronics and ICT). Compared to the Industry 4.0 markets, aerospace, nuclear technology, armaments, optoelectronics, and ICT demonstrate higher production activity and stronger competition in knowledge creation, which allows one to classify them as mature. These sectors' development prospects largely depend on the level of production globalization.

Case Studies of Countries – New AM Market Leaders

Over the past few decades a number of countries have significantly improved their positions on AM markets, so their success strategies are worthy of analysis. We will consider the examples of Vietnam, Ireland, Turkey, and South Korea.

In 20 years' time, Vietnam has managed to become one of the world leaders in the production of electronics by attracting foreign direct investment and supporting foreign companies. Ireland and Turkey have shown strong performance on the biotechnology market. In 10 years, Ireland has quadrupled its global market share, while Turkey shows the fastest growth of exports. In both countries, entry onto the markets under consideration was actively supported by the government, but in different ways. In Turkey this process was mainly driven by small and medium-sized businesses and in Ireland by global pharmaceutical corporations. South Korea is a model example of building up innovation potential and increasing the number of universities included in the top 100 rankings. The close integration of science and the real sector helped the country achieve a leading position in terms of the share of researchers leaving the real sector to work in academia.

Vietnam: the production of electronics

Having successfully integrated into global value chains, since the 2000s Vietnam has consolidated its leading position in electronics. In terms of production costs, the country has risen from 47th place among the world's exporters in 2001 to 12th in 2019. Currently, the share of electronics amounts to about 36% of gross national exports and 30% of total imports.

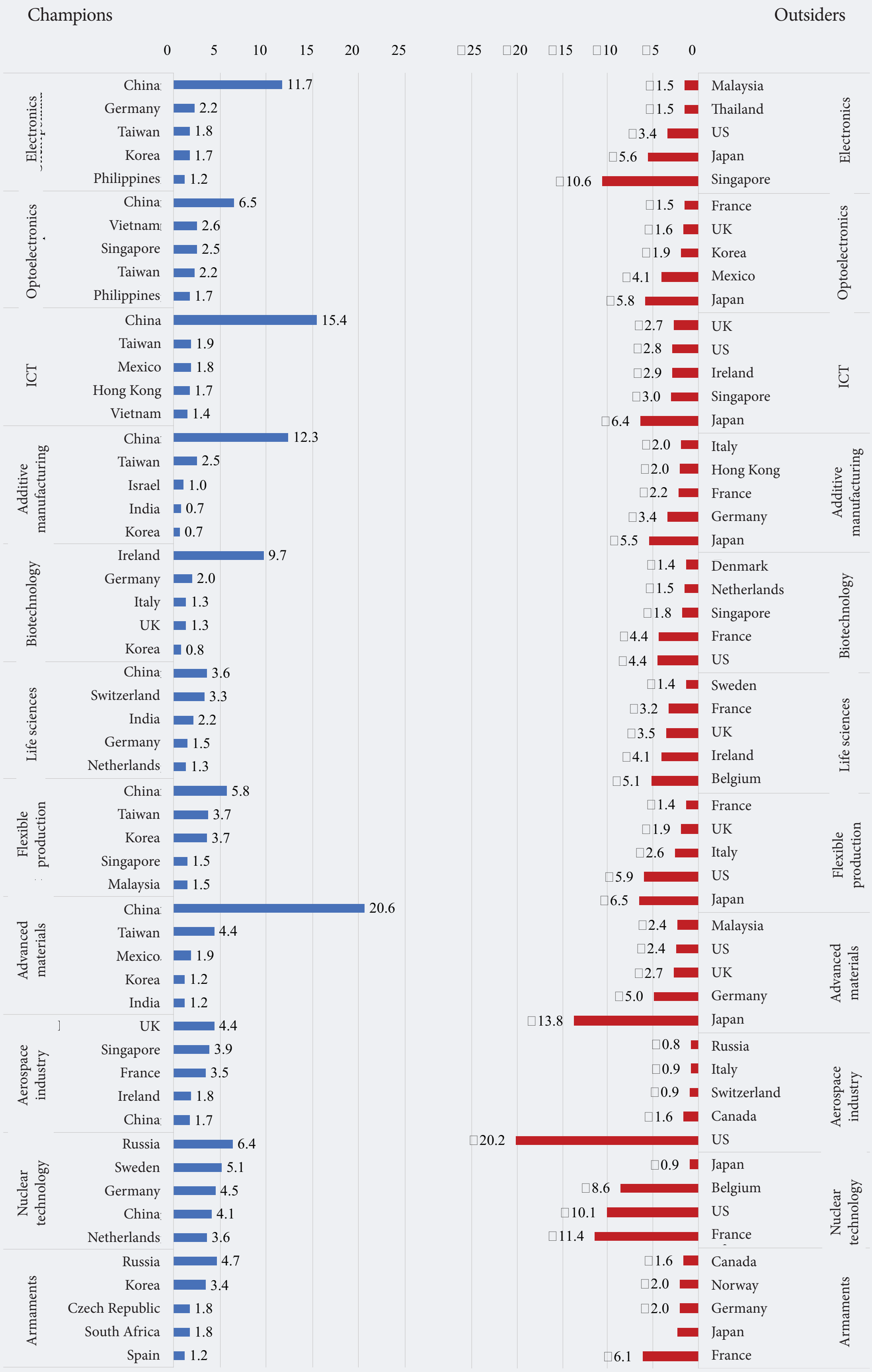
Consumer electronics make up the bulk of the exports: mobile phones, televisions, cameras (41%), electrical appliances (18.2%), and electronic integrated circuits (11.9%). Imports mainly consist of semi-finished products such as micro-components (40%) and semiconductor devices (6%). Most of the products are exported to China (19.3%), the US (18.2%), South Korea (9.1%), Hong Kong (4.9%), and Japan (4.9%), and imported from China (33%), South Korea (31%), Japan (8%), and the US (6.5%).

Vietnam is the only leading producer of electronics who is becoming increasingly dependent upon foreign components. The share of foreign value added in electronics exports which stood at 36% in 2005 grew to 44% by 2015. To compare, in China during the same time it decreased from 26% to 17%, in Malaysia from 45% to 37%, and in the Philippines from 27% to 22%. Multinational companies dominate the sector: although their number currently does not exceed 30% of all players, they account for about 90% of exports and control 80% of the domestic market. Among the largest investors are Samsung, LG, Intel, Canon, Compal Electronics, Jabil Circuit, Microsoft, Nokia, and Foxconn [*Ngoc, Binh,* 2019].

The accomplishments have been largely made possible by reforms in trade and industrial policies aimed at integrating the country into global value chains. Reduced tariffs to meet the requirements of the ASEAN Free Trade Area (AFTA) and the bilat-

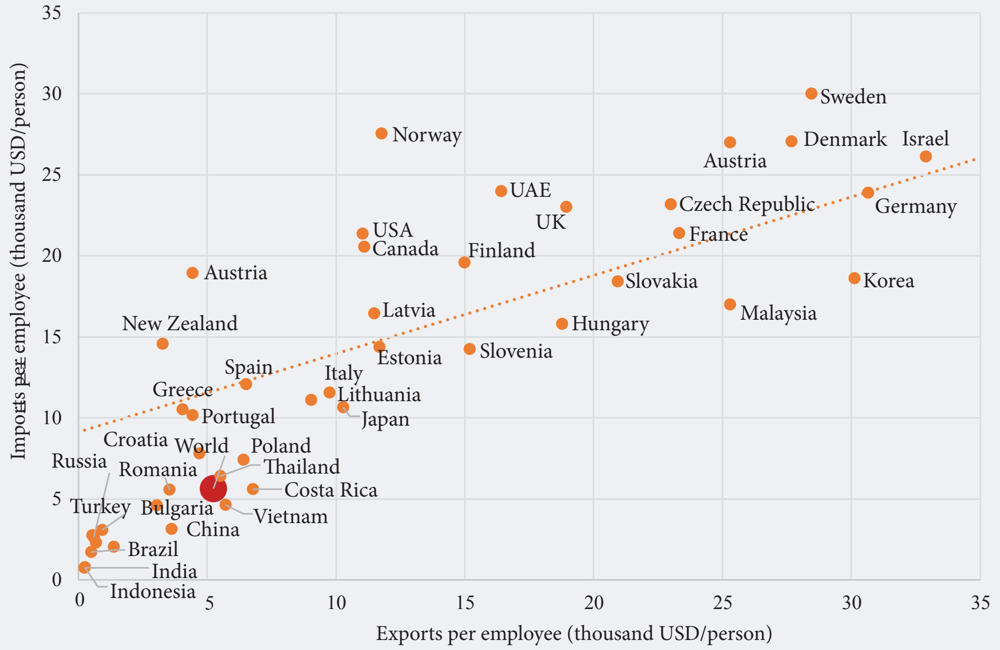
[8] Crunchbase is an online start-up information platform maintained by TechCrunch, a US technology publication (https://www.crunchbase.com). These results may be partly due to base bias: Crunchbase is headquartered in San Francisco, USA.

Figure 5. **AM Market "Outsiders" and "Champions" (difference in average market shares in 2002-2004 and 2016-2018)**



Sources: authors' calculations based on COMTRADE data and HS 2002 classification.

Figure 6. **Selected Countries' Positions in Terms of AM Product Import and Export Shares (truncated square): 2018**



Sources: authors' calculations based on COMTRADE data and HS 2017 classification.

eral trade agreement (BTA) with the United States resulted in zero import costs for equipment.

Vietnam started to shape its innovation policy only in the 2000s. A number of specific "vertical" strategies were adopted, e.g., in mechanical engineering in 2006, along with laws on information technologies (2006) and high technologies (2008), and an act simplifying the registration of private enterprises.[9] High-tech investors enjoy widespread support. Two major Samsung research centers operate in the country, where highly skilled local ICT engineers produce up to 10% of the company's global software output [*Do*, 2017]. Despite the advances in electronics, the prospects for technological innovation in the industry remain modest. Vietnam's experience in this field deepens the understanding of "classic" reasons for failures of attempts to promote growth by attracting foreign direct investment (shortage of skilled labor, etc.) [*Paus,* 2012; *Hausmann, Rodrik,* 2003; *Hobday et al.*, 2001; *Pham, Anh,* 2020]. The lack of domestic firms' competences is largely the result of the government policy aimed at supporting only foreign manufacturers in particular by reducing corporate taxes. This has led to the increased technological backwardness of local businesses, which affected not only the electronics sector but also the supporting industries, whose insufficient development determined the strong import dependency of manufacturers.

Ireland and Turkey: the development of bioindustry

American pharmaceutical giants (Pfizer, Merck, Abbott, etc.) played a key role in the emergence of the Irish biotechnology market, having built their production facilities there. The key factors for choosing this location were easy access to the European market, simplified drug certification procedures, favorable tax regime, high-quality business environment, and the absence of a language barrier.[10] The profit tax is one of the lowest in Europe, the total tax and contribution rate in 2019 was 26.1% (the EU average is 40%) [World Bank, 2019]. Intellectual property tax depreciation, reimbursable research and development (R&D) tax credits (25%), and patent box deductions (6.25%) are available for high-tech companies [PWC, 2020]. In addition to attracting the largest pharmaceutical companies, Ireland encourages R&D and domestic biotech start-up creation. The Science Foundation Ireland established in 2003 allocates at least a quarter of its budget to finance biotech and related projects [Science Foundation Ireland, 2003, 2019]. In 2006, a special R&D support program was launched with a budget of 2 million euros. The Medical and Engineering Technologies Centre was

[9] In the year the law on new companies was passed, their number doubled in just four months compared to 1999. https://www.bc.edu/content/dam/files/schools/law/lawreviews/journals/bciclr/25_1/03_TXT.htm, accessed on 14.03.2021.

[10] https://www.doingbusiness.org/en/data/exploreeconomies/ireland, accessed on 30.12.2020.

Table 5. **Comparison of AM Markets**

Market (average growth rate in 2002-2018) (%)	Concentration of manufacturers	Product type	Start-up creation	Inclusion of universities in Top 500 for relevant subject area
Industry 3.0				
Electronics (+5.2)	Low	Means of production (semiconductor devices)	High	Average
Optoelectronics (+5.5)	Average	End consumer products (input devices)	Average	Average
ICT (+5.0)	Average	End consumer products (computers)	Average	Average
Industry 4.0				
Additive manufacturing (+5.7)	Low	Means of production (3D printers and consumables)	High	Average
Biotechnology (+15.3)	Low	End consumer products (blood and immune sera)	High	High
Life sciences (+6.9)	Low	End consumer products (medicines)	High	High
Flexible production (+8.5)	Average	Means of production (machines and mechanical devices)	High	Average
Other AM markets				
New materials (+8.7)	High	Means of production (doped chemical elements and fibre optics)	Average	High
Aerospace industry(+4.9)	High	End consumer products (aircraft and spare parts)	Low	Average
Nuclear technology (1.3)	High	Means of production (uranium and heat dissipating elements)	low	Average
Armaments (+6.7)	High	Bombs and missiles	Low	-

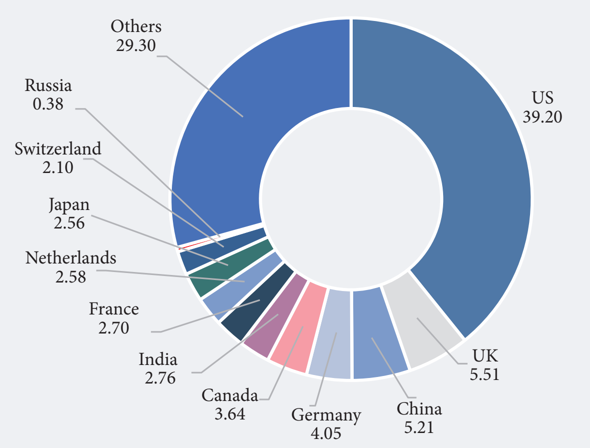
Note: the concentration of manufacturers was measured by analysing geographical concentration (monopolisation) of AM markets on the basis of the Herfindahl-Hirschman index. Start-up distribution was assessed by analysing CrunchBase data. Clustering of manufacturers, and start-up creation were estimated taking into account previous studies [*Tofail*, 2018; *Lineberger*, 2019; *Mohan, Roy*, 2017; *Narain*, 2016; Accenture, 2014; Deloitte, 2020a, 2020b; IAEA, 2020; UNODC, 2019]. The geography of universities is documented on the basis of their share in the top 3 for the home country (according to the QS World University rating, by subject). To link AMT product markets to the QS classifier, the following combinations of search terms were used: AMT (additive manufacturing + flexible production + aerospace industry) = QS (Mechanical, Aeronautical & Manufacturing Engineering); AMT (biotechnology + life sciences) = QS (Life Sciences & Medicine); AMT (electronics + optoelectronics) = QS (Electrical & Electronic Engineering); AMT (ICT) = QS (ICT); AMT (nuclear technology) = QS (Physics); AMT (new materials) = QS (Materials Science).

Sources: authors' calculations based on COMTRADE and Crunchbase data and HS 2002 classification.

established on the basis of the Galway-Mayo Institute of Technology to promote technology transfer and start-up development. In absolute terms, the number of successful biomedical companies is still small, but given the small population, in per capita terms, Ireland is among the leaders (Figure 5). Over the past 10 years, the local biopharmaceutical industry has attracted over 10 billion euros in fixed capital investments. By 2020, the 10 largest biopharmaceutical players had production facilities operating in the country.[11]

In Turkey, the biotech market began to take shape in the late 1990s, virtually from scratch [*Özdamar*, 2009]. The country focused on promoting local R&D and supporting innovative start-ups. The adoption of the National Science and Technology Strategy for 1993-2003 gave momentum to the development of R&D, with biotechnology set as a priority area [*Kose*, 2017]. During that period, about 20% of projects funded by Turkey's largest research foundation, the Scientific and Technological Research Council (TUBITAK) were in agrobiotech-

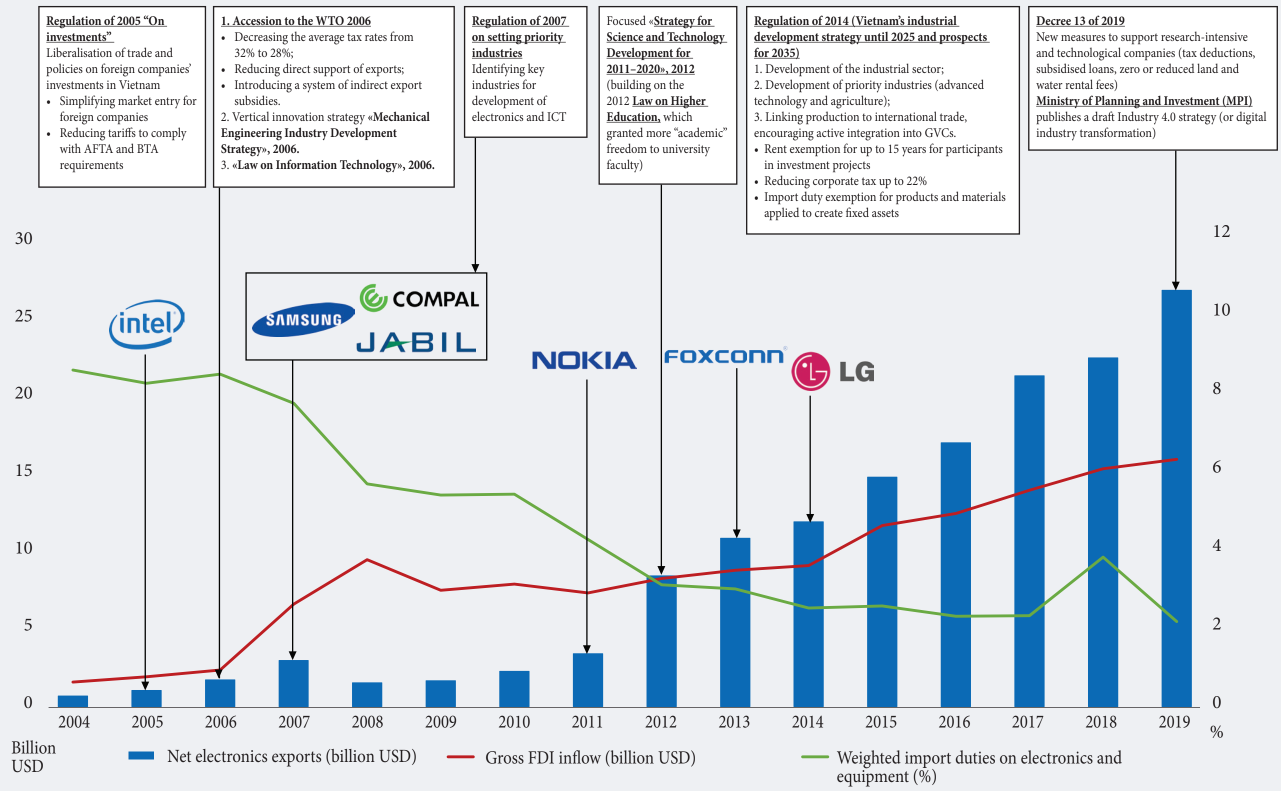
Figure 7. **Distribution of Innovative AMT Start-Ups by Country: 2020 (%)**



Sources: authors' calculations based on Crunchbase data.

[11] https://biopharmachemireland.ie/Sectors/BPCI/BPCI.nsf/vPages/Newsroom~ireland--the-global-biopharmachem,-location-of-choice-20-01-2020/$file/BPCI+Strategy+.pdf, accessed on 16.05.2021.

Figure 8. **Vietnam's Gross FDI Inflow, Net Exports, and Weighted Import Duties on Electronics and Equipment**



Note. Electronics exports include the following subgroups: optoelectronics, ICT, and electronics.
Sources: authors' calculations based on COMTRADE and WDI data and HS 2002 classification.

nology and other biotechnology groups [*Severcan et al.*, 2000]. Several specialized research programs were successfully implemented. EU funding helped local research laboratories establish partnerships in Europe, the US, and other countries [*Dundar, Akbarova*, 2011]. The Biotechnology Strategy and Action Plan 2015-2018 in addition to promoting R&D were focused on supporting innovative companies. From 2016 to 2019, commercial enterprises' R&D expenditures increased significantly; in 2019, almost three quarters of total expenditures were made by small and medium-sized businesses. Over the same period, the number of companies selling biotech products grew from 140 to 211.

Countries' biotechnology market growth models demonstrate a variety of approaches. In Ireland and Turkey, the government made the largest contribution to strengthening the sector's competitiveness. Ireland's approach seems to be more productive, but the actual industry development level depends on the political situation.

South Korea: promoting science-industry partnership

South Korea is a world leader in terms of R&D expenditures. In Bloomberg's Innovation Index 2020, the country is second only to Germany,[12] and in the Global Innovation Index, it ranks 11th among 129 economies (Germany is 9th).[13] South Korea has managed to closely integrate university science with the business environment, which helped the country achieve global leadership in terms of the share of researchers leaving the real sector to work in academia. In 2008, universities employed 70% of the country's PhDs and industry 20%, with the latter showing higher productivity [OECD, 2008].

In a short period of time South Korea has managed to bring several universities into the world's top 100, partly due to their deep integration into the business environment. Local universities lead in the share of co-publishing with the real sector. In the 2017 Times Higher Education ranking,[14] Pohang University of Science and Technology (POSTECH) is first by this indicator and Sungkyunkwan Uni-

[12] https://www.bloomberg.com/news/articles/2020-01-18/germany-breaks-korea-s-six-year-streak-as-most-innovative-nation, accessed on 14.03.2021.

[13] https://www.wipo.int/publications/ru/details.jsp?id=4514, accessed on 14.03.2021.

versity (SKKU) is eighth. These two universities' partnerships with chaebols on the South Korea Fair Trade Commission's list[15] deserve more detailed consideration.

POSTECH was established by the Pohang Steel Company (POSCO) in line with the Caltech model, as a small campus focused on research and technological innovation [*Cho,* 2014]. One of the university's subsidiaries is the Research Institute of Science and Technology (RIST) which implements short-term projects to accelerate the testing of innovative iron and steel processing technologies and in areas such as engineering, advanced materials, management, and economics. Both sides benefit from using common infrastructure while maintaining autonomy from each other.[16] Despite its small size, POSTECH has a developed partner network comprising 128 universities in 33 countries and is implementing a major joint project with the Max Planck Society.

SKKU, which has a long history as a traditional university, in the second half of the 20th century stagnated. In the late 1990s, Samsung affiliated its medical center with the university to conduct biomedical research, which brought the quality of medical services to a new level (Table 6). On this basis, a medical faculty was established at SKKU, along with the Centre for Semiconductor Research, the Computer Education Department, and the Graduate Business School. The university's development strategy largely serves Samsung's interests and is approved by the experts at the Samsung Economic Research Institute (SERI). SKKU currently has the status of corporate university and the company brand is present in the names of many of its divisions.

Discussion of the Results and Policy Effects

Over the past two decades the focus of industrial policy has shifted from providing selective protection, supporting import substitution, and betting on winners to promoting integration into value chains, digital transformation, supporting small and medium-sized businesses, and positioning the country in the new industrial revolution. Industrial policies of developed countries are becoming increasingly complex with long-term priorities flexibly adjusted to use the competitive potential to the maximum possible extent.

While the US, France, and Japan retain their leadership on the global AM markets, their shares in certain segments are gradually decreasing under pressure from new players undergoing a rapid structural transformation of their economies (Taiwan, South Korea, China). At the same time, the aforementioned leaders are switching to the emerging Industry 4.0 markets. The UK's positions in ICT and new materials have weakened, but the country expanded its presence on the biotechnology and aerospace markets. Germany has partially curtailed its activity in the new materials and additive manufacturing segments, but stepped it up in biotechnology, life sciences, and electronics.

Despite the global trends, Russian industrial policy remains vertical and hierarchical, focused on supporting large companies, while new players, including those in the growing AM sector, are facing problems with positioning. This is combined with lagging behind in terms of putting in place a sound regulation system for disruptive technology sectors. Development strategies for emerging ("sunrise") and declining ("sunset") industries must be separated. The emerging areas have high growth potential and scalability. However, some of these industries not only accelerate technological development but also require changes in the organization of traditional production, "cross-cutting" through a number of sectors (electronics, flexible production, new materials) [*Wang,* 1995].

Traditional and certain high-tech sectors alike are in decline (e.g., the textile and automotive industries). Falling into this group may be due to strategic decisions to reallocate resources and political support prompted by the lack of long-term prospects and the loss of a competitive edge.

Industry 4.0 markets are characterized by a high concentration of knowledge at universities combined with a high start-up activity, while Industry 3.0 ones tend to be dominated by large-scale production. The emerging AM markets imply the monopolization and rapid commercialization of new knowledge, while the features of "established" markets include in-depth specialization, consolidation of leading companies, and increased R&D competition. As a result, the approaches to supporting different AM markets vary. In the case of emerging markets, priority is given to improving the business climate, stepping up innovation, and building new competencies. Many countries, regardless of their development level, analyze the emerging AM market trends and adapt their sectoral strategies to match the Industry 4.0 context [UNIDO, 2020; *Dezhina, Ponomarev,* 2014]. Successful countries' examples demonstrate that no universal recipes for achieving leadership exist. In each case, the unique

[14] https://www.timeshighereducation.com/news/south-korean-universities-lead-way-on-industry-collaboration, accessed on 14.03.2021.

[15] The list of the largest Korean chaebols includes: Samsung, Hyundai Motor Company, SK, LG, Lotte, POSCO, Hanwha, and GS. http://www.businesskorea.co.kr/news/articleView.html?idxno=45210, accessed on 14.03.2021.

[16] E.g., in 2017 an agreement was signed on the joint development of the artificial intelligence ecosystem at POSCO and training specialists in the area. https://newsroom.posco.com/en/posco-group-university-partners-postech-ai-specialists/, accessed on 14.03.2021.

Table 6. **Key features of university-business integration in Korea as illustrated by POSTECH+POSKO and SKKU+Samsung case studies**

Case	POSTECH + POSKO	SKKU + Samsung
University rankings	POSTECH	SKKU
THE World	146	101
QS World	77	88
ARWU World	401-500	201-300
THE World (young)	8	-
QS World (50 under 50)	7	-
Size	3,087 students, 2% of them from abroad; 705 professors	22,482 students, 18% of them from abroad, 3,313 professors
Established	1986	1996
Concept, year	A small campus focused on research and technological innovation	Acquired by Samsung to build up Samsung Medical Centre's biomedical research expertise; SAMSUNG-SKKU joint venture established in 1996.
Main driver of integration	POSTECH president	Ministry of Education
Decision-making autonomy from corporate partner	High	Low
Cooperation interests	Mainly focused on the corporate partners' objectives	Much wider
Corporate investments in university	Total POSCO investments >2 billion USD, POSTECH budget = 320 million USD in 2020.	Since 1997 Samsung annually spends on the SKKU 50-100 million USD.

Sources: authors, based on [Stek, 2015; Cho, 2008, 2014; Innace, Dress, 1992] and THE, QS, ARWU, POSTECH data (http://www.postech.ac.kr/eng/about-postech/introduction-to-postech/postech-at-a-glance-2/#).

national and industrial context should be considered. Some economies have made rapid progress by attracting foreign capital. However, such results are only possible in small countries, while their sustainability depends on the behavior of a few major international companies. For large economies, attracting foreign investment involves high costs. The absence of required specialized competencies hampers the inflow of foreign investments. The adoption of new technologies by "sunset" industries can become a driver of competitiveness and future growth. To achieve leadership on the AM markets, it is important not only to have sufficient human capital, but to also ensure its circulation between the academic and real sectors. Finally, in countries that have achieved success on the AM markets, the balance (net migration) is shifting in favor of the latter [*Dayton,* 2020]. University faculty can apply their competencies in production and expand the range of practically tested ideas, which is critically important for promoting emerging markets' growth.

AM market development strategies tend to be based on involving a network of stakeholders [UNIDO, 2020; *Hausmann, Rodrik,* 2003, 2018; *Santiago,* 2018] and adopting the "stakeholder capitalism" model [*Schwab, Vanham,* 2021; WEF, 2019]. Their success largely depends on decision-makers' willingness and ability to forge a consistent vision [*Lee,* 2021], create opportunities for the early identification of trends [*Paunov, Planes-Satorra,* 2019], experiment, launch pilot projects, and select ideas and programs for scaling [*Hausmann, Rodrik,* 2003; *Rodrik,* 2018]. A top-down approach to coordinating technological change has demonstrated its effectiveness in catching-up countries such as Chile and Vietnam [UNIDO, 2020].

However, AMTs (at least some of them) are "cross-cutting" in nature, blurring the traditional sector boundaries. Therefore, approaches to managing the transformation of production due to the emergence of new technologies need to be constantly adjusted and adapted. Alternative tools and frameworks are required to handle increasingly complex production systems characterized by multiple interdependencies between industries, companies, technologies, and subsystems [*López-Gómez et al.,* 2017]. The "inclusiveness" and cross-cutting nature of new technologies require integrated government regulation and coordination [*Lee,* 2021]. As a result, establishing horizontal links between vertical strategies at the level of sectors, main actors, and stakeholders becomes relevant.

Sections "Methodology", "Structural features of global AM markets", "Positions of countries in AM markets", "Factors of country leadership in PP markets" were prepared within the framework of the grant of the President of the Russian Federation for state support of young Russian scientists "Assessment of Russia's participation in international trade in products related to the technologies of the Fourth Industrial Revolution, and its impact on improving Russia's position in global value chains "(agreement dated 20.04.2021 No. 075-15-2021-318). The section "Cases of countries - new leaders in integration onto the AM markets" was prepared within the framework of the project "Effects of Russia's participation on global markets of advanced production and consequences for Russian structural policy", carried out as part of the HSE Program of Fundamental Research in 2021.

References

Accenture (2014) The Flexible Manufacturer. Out-performing competition by changing the rules, Dublin: Accenture. https://www.accenture.com/t20150523T035031__w__/se-en/_acnmedia/Accenture/Conversion-Assets/DotCom/Documents/Global/PDF/Dualpub3/Accenture-Flexible-Manufacturer-Out-Performing-Competition-Changing-Rules.pdf, accessed 20.04.2021

Ardito L., D'Adda D., Petruzzelli A.M. (2018) Mapping innovation dynamics in the Internet of Things domain: Evidence from patent analysis. *Technological Forecasting and Social Change*, 136, 317-330. https://doi.org/10.1016/j.techfore.2017.04.022

Balassa B. (1965) Trade liberalisation and "revealed" comparative advantage. *The Manchester School*, 33(2), 99–123. https://doi.org/10.1111/j.1467-9957.1965.tb00050.x

Blanchet M., Rinn T., Dujin A., Geissler C. (2016) *The Industrie 4.0 Transition Quantified: How the Fourth Industrial Revolution Is Reshuffling the Economic, Social and Industrial Model. Think Act — Beyond Mainstream*, Munich: Roland Berger.

Castelo-Branco I., Cruz-Jesus F., Oliveira T. (2019) Assessing Industry 4.0 readiness in manufacturing: Evidence for the European Union. *Computers in Industry*, 107, 22–32. https://doi.org/10.1016/j.compind.2019.01.007

Cho M.H. (2008) Corporate Helix Model: The industry and triple helix networks. *International Journal of Technology and Globalisation*, 4(2), 103–120. https://doi.org/10.1504/IJTG.2008.018958

Cho M.H. (2014) Technological catch-up and the role of universities: South Korea's innovation-based growth explained through the Corporate Helix model. *Triple Helix*, 1(1), 1–20. https://doi.org/10.1186/s40604-014-0002-1

Dayton L. (2020) How South Korea made itself a global innovation leader. *Nature*, 581(7809), S54–S56). https://doi.org/10.1038/d41586-020-01466-7

Deloitte (2020a) *2021 Telecommunications industry outlook*, London: Deloitte. https://www2.deloitte.com/content/dam/Deloitte/us/Documents/technology-media-telecommunications/us-tmt-2021-outlook-for-the-us-tme-industry.pdf, accessed 30.12.2020.

Deloitte (2020b) *Global trends on the pharmaceutical and biotechnology market*, London: Deloitte. https://www2.deloitte.com/content/dam/Deloitte/ce/Documents/about-deloitte/ce_2020_global_life_sciences_outlook.pdf, accessed 30.12.2020.

Dezhina I., Ponomarev A. (2014) Advanced Manufacturing: New Emphasis in Industrial Development. *Foresight-Russia*, 8(2), 16–29 (in Russ.).

Do T.T.N. (2016) *Assessing and Improving Rational Antimicrobial Use in Urban and Rural Health Care Facilities in Vietnam*, Milton Keynes: Open University.

Dundar M., Akbarova Y. (2011) Current state of Biotechnology in Turkey. *Current Opinion in Biotechnology*, 22, S3–S6. https://doi.org/10.1016/j.copbio.2011.05.509

EY (2020) *Swiss Biotech Report*, London: Ernst & Young. https://www.swissbiotech.org/wp-content/uploads/2020/05/20200421-Swiss-Biotech-Report.pdf, accessed 30.12.2020.

Ferrantino M.J., Koopman R.B., Wang Z., Yinug F. (2010) The nature of US–China trade in advanced technology products. *Comparative Economic Studies*, 52(2), 207–224. https://doi.org/10.1057/ces.2010.6

Foster-McGregor N., Nomaler Ö., Verspagen B. (2019) Measuring the creation and adoption of new technologies using trade and patent data. Maastricht: UNU-MERIT. https://192.87.143.10/publications/wppdf/2019/wp2019-053.pdf, accessed 17.02.2021.

Fujii H., Managi S. (2018) Trends and priority shifts in artificial intelligence technology invention: A global patent analysis. *Economic Analysis and Policy*, 58, 60–69. https://doi.org/10.1016/j.eap.2017.12.006

Fulton M., Hon B. (2010) Managing advanced manufacturing technology (AMT) implementation in manufacturing SMEs. *International Journal of Productivity and Performance Management*, 59(4), 351–371. https://doi.org/10.1108/17410401011038900

Gasparatos A., Doll C.N., Esteban M., Ahmed A., Olang T.A. (2017) Renewable energy and biodiversity: Implications for transitioning to a Green Economy. *Renewable and Sustainable Energy Reviews*, 70, 161–184. https://doi.org/10.1016/j.rser.2016.08.030

Hallward-Driemeier M., Gaurav N. (2018) *Trouble in the Making? The Future of Manufacturing-Led Development*, Washington, DC: World Bank. https://doi.org/10.1596/978-1-4648-1174-6

Hausmann R., Rodrik D. (2003) Economic development as self-discovery. *Journal of Development Economics*, 72(2), 603–633. https://doi.org/10.1016/S0304-3878(03)00124-X

Hobday M., Cawson A., Kim S.R. (2001) Governance of technology in the electronics industries of East and South-East Asia. *Technovation*, 21(4), 209–226. https://doi.org/10.1016/S0166-4972(00)00038-9

Horváth D., Szabó R.Z. (2019) Driving forces and barriers of Industry 4.0: Do multinational and small and medium-sized companies have equal opportunities? *Technological Forecasting and Social Change*, 146, 119–132. https://doi.org/10.1016/j.techfore.2019.05.021

HSE (2018) Structural changes in the Russian economy and structural policy, Moscow: HSE (in Russ.).

IAEA (2020) Nuclear Technology Review 2020, Vienna: IAEA. https://www.iaea.org/sites/default/files/gc/gc64-inf2.pdf, accessed 30.12.2020.

Innace J.J., Dress A. (1992) *Igniting Steel: Korea's POSCO Lights the Way*, Tampa, FL: Global Village Press.

Kim G., Bae J. (2017) A novel approach to forecast promising technology through patent analysis. *Technological Forecasting and Social Change*, 117, 228–237. https://doi.org/10.1016/j.techfore.2016.11.023

Kim H.W., Qureshi Z. (eds.) (2020) *Growth in a time of change: Global and country perspectives on a new agenda*, Washington, D.C.: Brookings Institution Press.

Kose I. (2017) Science and Technology Policies in Turkey. In: *Researches on Science and Art in 21st Century Turkey* (eds. H. Arapgirlioglu, A. Atik, R.L. Elliott, R. Turgeon), Ankara: Gece Kitapligi, pp. 1759–1774.

Lee K. (2021) *Economics of technological leapfrogging,* Vienna: UNIDO.

Lin J.Y. (2012) *New Structural Economics: A Framework for Rethinking Development and Policy*, Washington, D.C.: The World Bank.

Lineberger R. (2019) *2020 Global Aerospace and Defense Industry Outlook*, London: Deloitte. https://www2.deloitte.com/content/dam/Deloitte/global/Documents/Manufacturing/gx-global-outlook-ad-2020.pdf, accessed 30.12.2020.

López-Gómez C., Leal-Ayala D., Palladino M., O'Sullivan E. (2017) *Emerging trends in global advanced manufacturing: Challenges, opportunities and policy responses*, Vienna, Manchester: UNIDO, Cambridge University.

Marginson S. (2007) Global university rankings: Implications in general and for Australia. *Journal of Higher Education Policy and Management*, 29(2), 131–142. https://doi.org/10.1080/13600800701351660

Marginson S., van der Wende M. (2007) To rank or to be ranked: The impact of global rankings in higher education. *Journal of Studies in International Education*, 11(3–4), 306–329. https://doi.org/10.1177/1028315307303544

Mohan A., Roy A. (2017) *A Strategic Investment Framework for Biotechnology Markets via Dynamic Asset Allocation and Class Diversification*. https://arxiv.org/abs/1710.03267, accessed 12.06.2021.

Narain A. (2016) Electronics in South Asia, Washington, D.C.: World Bank. https://openknowledge.worldbank.org/bitstream/handle/10986/25118/108827-WP-P146865-PUBLIC-electronics.pdf?sequence=1&isAllowed=y, accessed 14.04. 2021.

Naudé W., Surdej A., Cameron M. (2019) Ready for Industry 4.0? The Case of Central and Eastern Europe. In: *Industry 4.0 and Engineering for a Sustainable Future (eds.* M. Dastbaz, P. Cochrane), pp. 153–175. Heidelberg, Dordrecht, London, New York: Springer. https://doi.org/10.1007/978-3-030-12953-8_10

Ngoc T.T.B., Binh D.T. (2019) Vietnam's Electronics Industry: The Rise and Problems of Further Development. *Humanities & Social Sciences Reviews*, 7(4), 1–12. https://doi.org/10.18510/hssr.2019.741

OECD (2008) *OECD Review of Korea's Innovation Policy*, Paris: OECD. https://read.oecd-ilibrary.org/science-and-technology/oecd-reviews-of-innovation-policy-korea-2009_9789264067233-en#page1, accessed 30.12.2020.

Osborne-Kinch J., Coates D., Nolan L. (2017) The aircraft leasing industry in Ireland: Cross border flows and statistical treatment. *Central Bank of Ireland Quarterly Bulletin Articles*, 1, 58–69. https://www.centralbank.ie/docs/default-source/publications/quarterly-bulletins/quarterly-bulletin-signed-articles/the-aircraft-leasing-industry-in-ireland.pdf?sfvrsn=6, accessed 24.02.2021.

Özdamar T.H. (2009) Biotechnology in Turkey: An Overview. *Biotechnology Journal: Healthcare Nutrition Technology*, 4(7), 981–991. https://doi.org/10.1002/biot.200900145

Paunov C., Planes-Satorra S. (2019) *How are digital technologies changing innovation? Evidence from agriculture, the automotive industry and retail*, Paris: OECD. https://doi.org/10.1787/23074957

Paus E. (2012) Confronting the middle income trap: insights from small latecomers. *Studies in Comparative International Development*, 47(2), 115–138. https://doi.org/10.1007/s12116-012-9110-y

Pham H.S.T., Nguyen A.N., Johnston A. (2020) Economic policies and technological development of Vietnam's electronics industry. *Journal of the Asia Pacific Economy*, 1–22. https://doi.org/10.1080/13547860.2020.1809055

PWC (2020) *Investing in Ireland,* Dublin: PWC. https://www.pwc.ie/publications/2020/fdi-investing-in-ireland-issue-42.pdf , accessed 30.12. 2020.

Reischauer G. (2018) Industry 4.0 as policy-driven discourse to institutionalize innovation systems in manufacturing. *Technological Forecasting and Social Change*, 132, 26–33. https://doi.org/10.1016/j.techfore.2018.02.012

Rodrik D. (2018) New Technologies, Global Value Chains, and Developing Economies (NBER Working Paper 25164). Cambridge, MA: National Bureau of Economic Research. https://doi.org/10.3386/w25164

Santiago F. (2018) *You say you want a revolution: Strategic approaches to Industry 4.0 in middle-income countries*, Vienna: UNIDO.

Schwab K., Davis N. (2018) *Shaping the future of the fourth industrial revolution*, New York: Currency.

Schwab K., Vanham P. (2021) *Stakeholder capitalism: A global economy that works for progress, people and planet*, New York: John Wiley & Sons, Inc.

Science Foundation Ireland (2003) *Annual report and accounts 2003,* Dublin: Science Foundation Ireland. https://www.sfi.ie/research-news/publications/annual-reports/SFI-Annual-Report-2003.pdf, accessed 30.12. 2020.

Science Foundation Ireland (2019) *Annual report and accounts 2019,* Dublin: Science Foundation Ireland. https://www.sfi.ie/research-news/publications/annual-reports/SFI-2019-Annual-Report-(English).pdf, accessed 30.12. 2020.

Severcan F., Ozan A., Haris P.I. (2000) Development of biotechnology education in Turkey. *Biochemical Education*, 28(1), 36–38. https://doi.org/10.1111/j.1539-3429.2000.tb00011.x

Shipp S.S., Gupta N., Lal B., Scott J.A., Weber C.L., Finnin M.S., Thomas S. (2012) *Emerging global trends in advanced manufacturing*, Alexandria VA: Institute For Defense Analyses.

Simachev Y., Kuzyk M., Pogrebnyak E. (2018) Federal Industrial Policy: Basic Models and Russian Practice. *The Journal of the New Economic Association*, 3 (39), 146–154. DOI: 10.31737/2221-2264-2018-39-3-8 (in Russ.).

Simachev Y.V., Fedyunina A., Kuzyk M.G. (2020) Industrial revolution 4.0 in the BRICS countries: What are the challenges for industrial policy? *BRICS Journal of Economics,* 1(3), 4–22.

Stek P. (2015) The strategic alliance between Sungkyunkwan University and the Samsung Group: South Korean exceptionalism or new global model? *Helice*, 4. https://www.triplehelixassociation.org/helice/volume-4-2015/helice-issue-12/the-strategic-alliance-between-sungkyunkwan-university-and-the-samsung-group-south-korean-exceptionalism-or-new-global-model, accessed 15.12.2020.

STPI (2010) *White Papers on Advanced Manufacturing Questions. Draft Working Papers Version 040510*, Washington, DC: Science and Technology Policy Institute. https://www.nist.gov/system/files/documents/2017/05/09/advanced-manuf-papers.pdf , accessed 06. 04.2020.

Tansan B., Gökbulut A., Targotay Ç., Tevfik E. (2016) *Industry 4.0 in Turkey as an Imperative for Global Competitiveness: An Emerging Market Perspective,* Istanbul: TÜSİAD.

Tofail S.A., Koumoulos E.P., Bandyopadhyay A., Bose S., O'Donoghue L., Charitidis C. (2018) Additive manufacturing: Scientific and technological challenges, market uptake and opportunities. *Materials Today*, 21(1), 22–37. https://doi.org/10.1016/j.mattod.2017.07.001

Tuesta E.F., Garcia-Zorita C., Ayllon R.R., Sanz-Casado E. (2019) Does a Country/Region's Economic Status Affect Its Universities' Presence in International Rankings? *Journal of Data and Information Science*, 4(2), 56–78. https://doi.org/10.2478/jdis-2019-0009

UNCTAD (2019) *Contribution of Turkey to the Commission on Science and Technology for Development (CSTD) 2018–19 Priority Theme on 'The Impact of Rapid Technological Change on Sustainable Development'*, Vienna: UNCTAD. https://unctad.org/system/files/non-official-document/CSTD_2019_IPanel_T1_RapidTech_con11_Turkey_en.pdf, accessed 27.04.2021.

UNIDO (2020) *Competitive Industrial Performance Index 2020: Country Profiles,* Vienna: UNIDO. https://stat.unido.org/content/publications/competitive-industrial-performance-index-2020%253a-country-profiles?_ga=2.161772281.455182122.1612350573-1676216167.1612350573, accessed 30.12.2020.

UNODC (2019) *The legal market in firearms*, Vienna: UNODC. https://www.unodc.org/documents/e4j/Module_03_-_Legal_Market_in_Firearms_FINAL.pdf, accessed 30.12.2020.

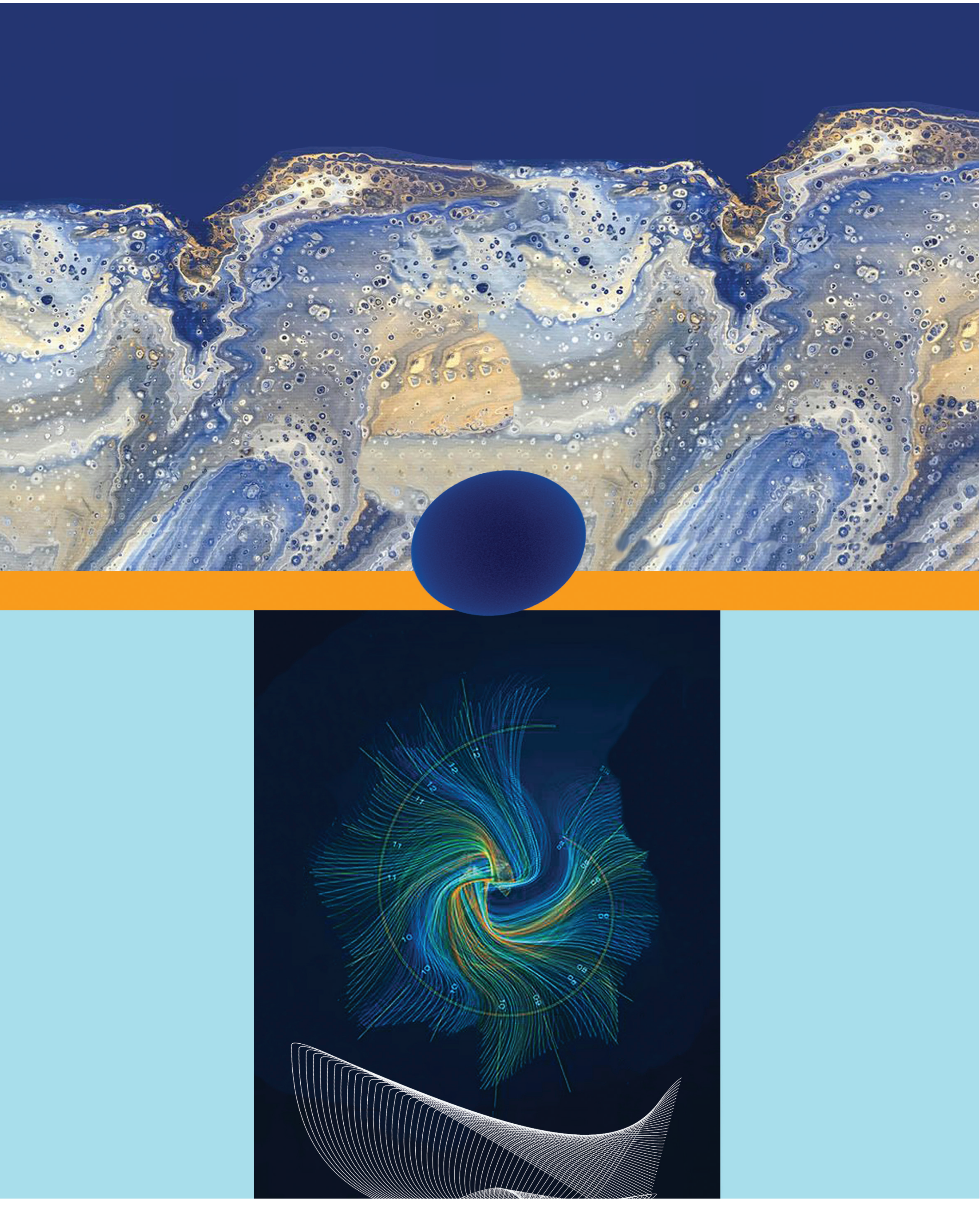
van Wilgenburg B., van Wilgenburg K., Paisner K., van Deventer S., Rooswinkel R.W. (2019) Mapping the European startup landscape. *Nature Biotechnology*, 37(4), 345–349. https://doi.org/10.1038/s41587-019-0076-4

Wang V.W.C. (1995) Developing the information industry in Taiwan: Entrepreneurial state, guerrilla capitalists, and accommodative technologists. *Pacific Affairs*, 68(4), 551–576. https://doi.org/10.2307/2761276

WEF (2019) *Global Technology Governance A Multistakeholder Approach,* Geneva: WEF. http://www3.weforum.org/docs/WEF_Global_Technology_Governance.pdf, accessed 30.12.2020.

World Bank (2016) *World Development Report 2016: Digital Dividends*, Washington, D.C.: World Bank.

World Bank (2019) *World Development Report 2020: Trading for Development in the Age of Global Value Chains,* Washington, D.C.: World Bank.



Identification of the Technology Frontier

Evgeny Balatsky
Professor and Head[a], Principal Research Scientist[b], ebalatsky@inbox.ru

[a] Macroeconomic Regulation Center, Financial University under the Government of the Russian Federation, 49 Leningradsky Prospekt, Moscow, 125993, Russian Federation

[b] Central Economics and Mathematics Institute of the Russian Academy of Sciences, 47 Nakhimov Prospekt, Moscow, 117418, Russian Federation

Abstract

The subject of this study is the innovation market. To understand the laws of its functioning, this article introduces the concept of a technology frontier. This is understood as the relative productivity of labor (relative to the technological leader – the United States), the achievement of which makes it justified for developing economies to move from large-scale borrowing of foreign new technologies to their development within the country. The purpose of the article is to determine the specified frontier for which a simple econometric model based on international statistics for 61 countries is proposed. The modeling methodology extends Schumpeterian ideas about two innovative stages: the creation and dissemination of technologies. The technology frontier is interpreted as the point of intersection of the curve of specific costs for the purchase of technologies abroad with the curve of costs for their development and creation within the country. It is assumed that both types of costs depend upon the relative labor productivity. The share of R&D costs in GDP was used as a proxy variable for technology creation costs and the ratio of the balance of payments for intellectual property to GDP was used as a proxy variable for borrowing costs. To improve upon the accuracy of the calculations, countries were clustered into two groups: advanced, for which the technology frontier has been crossed and their own developments of new technologies prevail, and developing, for which the problem of the technology frontier remains important. Estimates have shown that the current value of the technology frontier is in the region of 70% of labor productivity in the United States. The comparison with previous estimates shows that this value tends to increase, which creates additional difficulties for the transition of catching-up countries from borrowing to creating new technologies.

Keywords: technology frontier; labor productivity; technology borrowing; innovation

Citation: Balatsky E. (2021) Identification of the Technology Frontier. *Foresight and STI Governance*, 15(3), 23–34. DOI: 10.17323/2500-2597.2021.3.23.34

Introduction

In terms of technological development level, countries can be divided into leaders (the core) and followers (the periphery and semi-periphery). To reduce technological lag, a mix of new technology development (innovation) or borrowing (imitation) strategies can be used, in various proportions. Despite the seeming "simplicity" of the imitation approach, only a few of the countries that opted for this model managed to come closer to the leaders.

Many factors hinder the implementation of an effective innovation policy. One of them is the difficulty of defining the technological frontier (TF) — a critical point (reflecting relative labor productivity compared with a leader country) beyond which it would make sense to move from borrowing foreign technologies to developing domestic ones. Underestimating this factor leads to a situation where, if the country's development level has exceeded the TF but the national strategy remains focused on technology borrowing, the economy falls into a trap and further progress is hindered [*Dementyev*, 2006]. And vice versa, trying to implement major research and development (R&D) projects while the national economy remains significantly below the TF leads to pointless expenditures due to the lack of demand for advanced production technologies.

The goal of this paper is to develop an algorithm for identifying the TF on the basis of international statistics. Taking this parameter into account provides significant advantages, since it allows one to determine the moment for switching from an imitation to an innovation strategy in a timely manner.

The Technological Frontier Concept

In the economic literature, the TF concept emerged in the framework of endogenous economic growth theories. It is closely related to the concept of aggregate or total factor productivity (TFP). This term (occasionally the term "Solow residual" is used in its stead) implies estimating the technological progress in an economy as the difference in the weighted growth rates of output and other production factors [*Solow,* 1956]. In the canonical models, the latter include labor and physical capital, while more sophisticated variations add human resources, quality of institutions, infrastructure, and so on. The classical Solow model comprises prerequisites such as a constant economy of scale, perfect competition conditions, and companies operating at the limit of their production capabilities.

Various "frontier-based" methods to assess technological progress have been proposed to eliminate these factors: non-parametric envelope methods (linear programming) [*Farrell*, 1957] and stochastic production frontier models (panel data) [*Aigner et al.,* 1977]. Both these approaches are focused on assessing technological progress on the basis of modeling the production frontier by identifying the highest productivity of the technological factor. In a number of studies, the frontier is called "technological" [*Caselli et al.,* 2006]. However, this understanding of TF implies taking into account the technological capabilities of the economy, i.e., it involves an extended understanding of the concept in question. Such an interpretation is rather complicated, since it requires one to consider a set of the most efficient production methods available under certain conditions (for a company, industry, or country) [*Sato,* 1974]. Furthermore, in English this concept has a double meaning. "Frontier" technology means a technology that can radically transform the established economic or social processes. These include, for example, renewable energy, artificial intelligence, electric vehicles, and so on [UNCTAD, 2018]. The totality of such technologies available on the market define the technology frontier as a limit of technological capabilities.

The extended interpretation of TF identifies it with the technological factor in the broadest sense of the word, while in natural sciences and engineering TF has a narrower meaning: it is a threshold value (e.g. temperature) at which the observed object or process fundamentally change their properties (e.g. melting point). This understanding is increasingly used by economists who model companies' or countries' behavior when they move on from investing in buying foreign technologies (imitation) to conducting their own R&D (innovation).

Attempts to model organizations' behavior when they change their investment mode have been made since the 1960s [*Scherer,* 1967; *Baldwin, Childs,* 1969]. Initially the cost-based approach was used: expenditures on procuring technology (imitation) were seen as advantageous due to their quick payback period. However, as the company loses its market share, the profits generated by applying the newly acquired technology rapidly diminish. On the other hand, the costs associated with in-house development are less attractive in the short term, but in the longer run they turn out to be more than justified. Thus, taking into account the market specifics, companies always face a choice: imitate innovations or create them.

This approach looks promising but becomes more complicated due to the need to assess alternative effects over time. Subsequently it was applied at the macro-level. A model was developed which considers the industry as a competitive arena for innovator and imitator companies and describes the impact of corporate strategies on economic growth and the effectiveness of government R&D subsidies [*Segerstrom,* 1991]. Still later, dividing countries into technological leaders and followers allowed for identifying policies that helped each group achieve the highest growth rate [*Sala-i-Martin, Barro,* 1995]. A dichotomy was introduced for the technological regime not just of companies (countries), but also numerous other market players, which became the basis for subsequent empirical research. Though the term TF was not directly mentioned in these publications, they prepared the ground for its new understanding.

A simple rule was formulated: disruptive innovations (i.e. those reaching the TF) become profitable when the return on technological advances increases and the scale of innovation exceeds the R&D costs [*Paulson Gjerde et al.,* 2002]. Initially this rule was applied to individual companies, but it can be easily applied to industries and countries. A basic pattern was revealed: less developed economies tend to choose the imitation path, while more advanced ones adopt innovation strategies. The distance from the global TF is a measure of an economy's maturity [*Acemoglu et al.,* 2003, 2006]. Obviously, the switch occurs relatively smoothly when both methods of technological development can coexist. The closer a country gets to the TF, the more complex the technologies it borrows become, while the importance of domestic innovations based on human capital and national S&T groundwork increases [*Acemoglu,* 1997]. Innovations emerge in industries (economies) which belong in the "frontier" zone or are close to it; the need for technology borrowing increases the farther a national economy is from the global TF level [*Cincera, van Pottelsberghe,* 2001; *Polterovich,* 2009]. Thus, the idea of a mixed strategy was suggested, when borrowing new technologies and developing them take place at the same time and the growth is evident in increased innovation activity.

In general, the extended interpretation of TF is due to the accelerated pace of technological change itself. For example, the commercialization of one of the "frontier" technologies can significantly shift the TF the world over. There is a fundamental difference between innovation "for oneself" implemented by, among other things, borrowing technologies and a real innovation for the market. Sales of the latter mean recognition by consumers, which to a certain extent "pushes" the TF [*Yasin, Snegovaya*, 2018]. Therefore, the extended interpretation of TF is more abstract and more difficult to verify, while it meaningfully explains companies' and countries' development paths and serves as an element in the system applied to plan further progress.

TF Quantification Practices

Let us consider certain approaches to identifying the TF.

1. Defining TF as TFP in traditional production functions [*Bessonova,* 2007]: ,

$Y = AK^{\alpha}L^{1-\alpha}$,

where
Y is total output;
K is capital;
L is labor;
α is elasticity;
A is total factor productivity interpreted as TF.

The authors would like to remind the reader that more complex and realistic modifications are developed by introducing additional factors or disaggregating the basic components (e.g. breaking labor down into skilled and unskilled) [*Caselli et al.,* 2006]. The main advantage of this approach is the possibility of introducing two TF types: 1) the distance between the country and its notional limit, i.e., the maximum attainable productivity, and 2) the distance between the country's notional limit and the global TF [*Filippetti, Peyrache,* 2017]. The second approach has proven its usefulness in explaining the economic growth rate considering the country's technological lag [*Battisti et al.,* 2018; *Rabe,* 2016]. It focuses on the economy's abstract marginal technological potential expressed in dimensionless units.

2. *Defining TF as the ratio of labor productivity in the economy under consideration to that in a leading country* (typically the US) taking into account purchasing power parity [*Aghion et al.,* 2005] allows one to see this value as a dividing line between the imitation and innovation behavior modes. The TF value is often introduced into equations containing other macroeconomic variables such as value added, R&D expenditures, intermediate products costs, etc. A similar scheme is applied at the micro-level, with the only difference being that one or several competing companies are introduced into the equation system to calculate profit margins associated with choosing the innovation mode, while the TF turns out to be equal to the highest productivity among all companies [*Benhabib et al.,* 2017]. Thus, in these studies the very TF concept is essentially replaced by the relative labor productivity indicator. As a result, the distance to the technological leader is considered, but strictly speaking, the point of switching from borrowing innovations to creating them is not identified.

Whereas the country- or industry-level empirical data is usually collected by national statistical offices, sociological studies are conducted to estimate the TFs for individual companies. For example, a survey of Spanish businesses allowed for modeling the impact of the technological gap between companies and the leading firm based on their choice of innovation creation or borrowing; the TF was measured as TFP [*Gombau, Segarra,* 2011]. A similar survey was conducted in African countries, but the TF was not considered in the context of imitation versus innovation [*Cirera et al.,* 2017]. Case studies of Portuguese enterprises revealed the impact of structural reforms on changing the distance from the TF [*Gouveia et al.,* 2017]. There is a study assessing the efficiency of R&D expenditures depending on one's proximity to the TF based on a survey of about 550 companies with the highest R&D expenditures in the world [Andrade et al., 2018]. The above indicates that a not very transparent construct (i.e., relative TFP) was applied as TF here too. Plus, measuring the TF is relatively simple: the calculations again boil down to calculating the gap between the maximum (frontier) and actual TFP value for numerous market participants.

3. Identifying the TF on the basis of qualitative company surveys. This approach is based on a closed-ended question (with multiple answer options to choose from) about the estimated level of technologies applied by the company (more advanced compared to competitors, about the same, or inferior) [*Alder*, 2010]. In particular, it was used in the 2002-2008 World Bank study covering more than 9,000 enterprises.[1] Another variant of the question was used in a survey of Korean companies: "What is the purpose of applying innovations?" The provided answer options allowed one to classify the respondents' technological strategies: opening new markets (companies at the TF level), increasing market share or diversifying one's product line (followers), or changing product design (outsiders) [*No, Seo,* 2014]. The weakness of this approach is due to the fact that surveys are conducted rarely, their results are not internationally comparable, and companies are grouped using non-representative samples.

4. Indirect assessment of the TF based on Tobin's Q ratio (the ratio of the company assets' market value to their replacement value) [*Coad,* 2008]. Up-to-date stock market data allows for identifying changes in companies' behavior patterns depending on their performance. However, an increase in Tobin's Q ratio is not always caused by the firm's increased technological level.

Thus, each of the "digitization" methods described in the international literature has its strengths and weaknesses depending on the context of the analysis. In Russia the term "technological frontier" is applied purely descriptively. No examples of its quantitative interpretation and, therefore, inclusion in macroeconomic models, have been found. In the scope of the most promising approach to understanding TF, a theory of the shift from borrowing technologies to developing them has been proposed [*Polterovich, Tonis,* 2005]. TF was interpreted as the relative labor productivity (compared with the US), exceeding which makes the country's own R&D products economically viable. Two econometric relationships were identified that describe the costs of imitation and innovation, which in our previous work [*Balatsky,* 2012] were used to directly calculate the TF. The fundamental possibility of a simple analytical solution to a similar problem was demonstrated. To the best of our knowledge, no other attempts to quantify TF (according to the modern understanding of it as the point of shifting from one behavior to another) were made in Russia. At the same time, the initial data in the aforementioned study was very generalized and required substantial refinements. Thus, the TF problem by its very nature implies the need for more subtle methodological approaches. For example, the question about how universal TF is, spatially and temporally, remains open. In particular, it is unclear how much the TF differs across groups of nations at different economic development levels and in which direction it drifts over time. The subsequent constructs are intended to answer these questions.

A Theoretical Innovation Market Model

Continuing the logic presented in [*Polterovich, Tonis,* 2005; *Balatsky,* 2012], we will consider two sides of the innovation market. There are two possible interpretations of market interactions: at the micro- (costs), and macro-economic (market) levels. The microeconomic level was addressed in the aforementioned studies and is more traditional.

Let S be the country's unit costs of buying on the open technology market (royalty balance) and D its R&D expenditures. The main assumption is that these costs are functions of labor productivity P. It would be reasonable to believe that as the country's technological level increases (relative labor productivity, typically compared to the notional leader, the US), its unit R&D costs decrease, while productivity growth leads to increased expenditures on technology borrowing due to the need to buy ever more advanced and expensive technologies. In this case, the choice of national innovation strategy can be described by a generalized function of unit costs W which combines the two types of expenditures with the weight coefficient ζ:

$$W = \zeta S + (1 - \zeta) D \qquad (1)$$

Optimizing combination (1) by the weight coefficient results in the simplest condition:

$$dW/d\zeta = S - D \qquad (2)$$

Thus, the optimum is achieved when the two-unit cost types are equal. A rational national strategy does not imply choosing the right proportion between these two types of costs and implementing a mixed approach. On the contrary, it entails following a simple rule: if $D>S$, then $dW/d\zeta<0$, and the country mainly uses its own R&D products. Otherwise, the strategy to follow is massive technology borrowing. In practice a mixed strategy is usually applied, with the clear dominance of one cost type. For us, the abovementioned moment when one of the "pure" innovation strategies prevails is important.

[1] https://www.enterprisesurveys.org/en/enterprisesurveys, accessed on: 21.06.2021.

For simplicity, along with many previous studies we will assume that cost dependencies are described by the simplest linear labor productivity functions:

$$D = \alpha + \beta P \quad (3)$$

$$S = \alpha^* + \beta^* P, \quad (4)$$

where α, α*, β and β* are parameters.

Then the equilibrium labor productivity value P* with S=D becomes the desired TF:

$$P^* = -\frac{\alpha^* - \alpha}{\beta^* - \beta} \quad (5)$$

According to the second interpretation (the market or macro-economic one), equation (3) describes the demand for technological know-how, while equation (4) describes the supply of technological innovations. Here it would be reasonable to assume that demand (the economy's need for innovations) decreases with the growth of labor productivity, while the supply (the ability to generate royalties) increases. Then equilibrium on the royalty market is achieved when supply and demand are equal, which determines the TF (5).

Despite its relative simplicity, the proposed innovation market model yields meaningful and verifiable results. Let us consider the possibility of its econometric verification, for which it is sufficient to construct regressions of equations (3) and (4).

Methodology of the Study

Initial data

The applied calculations to identify the TF are based on statistical data from the World Development Indicators database[2] for 1996-2017 (22 observations). The following variables were used:

- P is the relative labor productivity (GDP per worker employed in the economy)[3];
- D is internal R&D expenditures as a share of GDP (proxy variable for innovation unit costs);
- C is fixed capital investments as a share of GDP (*gross fixed capital formation*);
- S is the ratio of revenues (from technology exports) and payments for intellectual property (technology imports) as a share of GDP (proxy variable for technology borrowing unit costs).

The choice of proxy variables was based on the popular practice of modeling companies' or national economies' innovation (R&D expenditures) and imitation (procurement of off-the-shelf technologies) strategies [*Schewe,* 1996; *Slivko, Theilen,* 2014]. All indicators in the range under consideration were processed using the geometric mean method except S, to which the arithmetic mean principle was applied due to the negative values. Sixty-one economies were included in the final statistical sample, for which data was available for at least 11 observations of each variable. Missing values were reconstructed as the average of the two adjacent points. In several cases the averaging out was performed over an incomplete time series. Accordingly, econometric dependences were built on the basis of a spatial sample, since analyzing panel data was not suitable for identifying the overall dependence of specific periods with the subsequent comparison of the TFs over time. In addition, the high volatility of S was noted over long time ranges. All variables except for the share of investments in fixed assets were subjected to standard normalization *x*: $x_n=(x-x_{vin})/(x_{max}-x_{min})$, for the whole sample or for the relevant cluster.

Clustering economies

To make sure the calculations are correct, it must first be determined which economies should be considered for TF identification as well as those for which this objective would be meaningless. For this purpose, the initial array of countries was clustered to subsequently build specific regression dependences for the resulting groups. Obviously, dependences will turn out to be different for country clusters with different development levels. Using a single model for the entire sample would likely yield overestimated or underestimated results. The models previously applied for a single array of countries [*Polterovich, Tonis,* 2005] were refined here. We have also used the most recent data, which adjusted the previous estimates.

Clustering amounts to breaking economies down into advanced and catching-up ones. A two-step procedure was applied for this purpose. At the first stage, machine methods were used for the initial identification of several groups of countries. In most cases single, full, and average connections and centroids were calculated to determine the distance between the clusters, using the Ward method (ward.D). The centroid technique demonstrates the greatest correlation with other instruments, while the Ward method identifies uniqueness. All approaches except the last one produced one disproportionately large cluster and several small ones. This result was unsatisfactory, since too small samples do not allow for building statistically significant regressions. Nevertheless, at this stage a primary pattern could be observed: whatever grouping method was used, the first echelon mainly included countries whose R&D expenditures as a share in GDP exceeded 1.5%. The preliminary clustering produced two groups of countries, primarily based on the R&D expenditures value. We were unable to build any significant

[2] https://datacatalog.worldbank.org/dataset/world-development-indicators, accessed on 21.06.2021.

[3] Each country's productivity value was compared to that of the US which was chosen as the base (benchmark).

regressions for these clusters, despite the obvious relationship between the variables.

At the second stage the machine clustering was calibrated by three sequential operations: sorting the economies by the D indicator value in descending order, calculating the correlation coefficients between D and P (a sequential assessment of the correlation for the top two, three, four, etc. countries), finding threshold points where the correlation coefficient's sign changes, and "humps" signaling changes in the strength of the correlation (Figure 1). Figure 1 shows the distribution of countries by the nature of the relationship between indicators D and P with the exception of South Korea. Accordingly, all countries with values higher than the Czech Republic's were included in the first cluster, since starting from it the correlation coefficient becomes less than 0.2 in modulus (which indicates a relatively weak connection). Interestingly, 16 out of 18 countries in the first cluster were included there by the machine method. Breaking the group of catching-up countries down into sub-clusters did not yield a positive result. Moreover, an additional manual calibration of the second cluster using sliding correlation coefficients showed that the parameter D was not pivotal for it and neither was S. However, sorting the second cluster by the indicator P did produce a positive result, albeit without an explicit sinusoid as in the first cluster. The final number of countries included in the second cluster was 43.

Empirical Identification of the Technological Frontier

The initial hypothesis for subsequent calculations was the premise that different country clusters would have different TF values. The final test of the proposed hypothesis and the validity of clustering the economies comprised building two econometric dependences. If models can be built for each cluster, would have good statistical characteristics, and yield consistent results, we can assume the clusters were identified correctly. Otherwise, the clustering should be considered invalid and different procedures applied to perform it. Differences in the TF values across clusters should confirm the heterogeneity of this parameter for the global economy. For the first cluster (which includes advanced countries) the following pair of econometric relationships was obtained:

$$D = \underset{(6,497)}{0,813} - \underset{(1,724)}{0,231}P \quad 6)$$

N=18; R^2=0.157; BP=2.18 (significance point 0.14); GQ=0.18 (0.99).

$$S = \underset{(6,141)}{0,970} - \underset{(2,224)}{0,376}P \quad (7)$$

N=18; R^2=0.236; BP=0.01 (0.96); GQ=3.29 (0.07).

The resulting models (6) and (7) have satisfactory statistical characteristics. The β coefficient in model (6) is significant at an 11% level, which is acceptable for the sample with values averaged out for a long interval. The absence of heteroscedasticity was verified using the Brousch-Pagan (BP) and Goldfeld-Quandt (GQ) tests, with satisfactory results for both models. A more thorough verification of models (5)-(6) was not carried out since its results were used for the applied calculations of a "virtual" TF which is of an auxiliary nature (see below).

Given the average value of investments' share in GDP for the first group of countries at 22.6%, the calculation of TF for models (6) and (7) yielded the value P*=108.2%, which is outside the acceptable range. In other words, econometric calculations confirmed that for the advanced economies cluster, the TF problem is meaningless, while the TF itself becomes "virtual". This fact requires a comment from the point of view of the structure of models (6) and (7). In a conventional situation two effects normally tend to occur: R&D learning ($\beta<0$) and the growth of borrowed technologies' costs ($\beta^*>0$). However, for advanced countries, the latter effect was inversed ($\beta^*<0$), which has a rather transparent interpretation: for countries supplying innovations to the market, technologies become even more accessible and cheap due to labor productivity growth. Thus, for leader countries both the supply and demand curves become decreasing. They intersect beyond the 100% point since along the entire abscissa axis the unit costs of creating new technologies domestically for these countries remain lower than the unit costs of foreign equipment (Figure 2).

For the second cluster (catching-up countries), the following econometric relationships were identified:

$$D = -\underset{(2,468)}{0.427} + \underset{(4.318)}{0.677}P + \underset{(3.862)}{0.028}C \quad (8)$$

N=43; R^2=0.448; BP=0.31 (0.86); GQ=0.33 (0.99); Chow=1.01 (0.40).

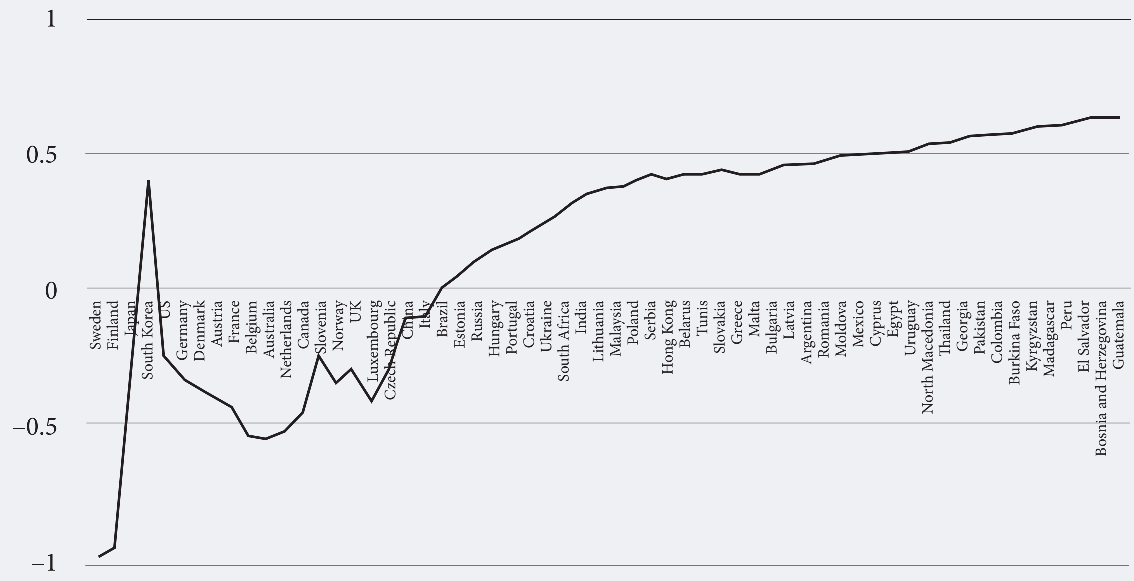
$$S = \underset{(15.504)}{0.086} - \underset{(1.974)}{0.275}P \quad (9)$$

N=43; R^2=0.087; BP=1.27 (0.26); GQ=2.75 (0.02), BP_{wt}=1.51 (0.47); Chow=1.84 (0.17).

The constructed models (8) and (9) also have satisfactory statistical characteristics. The β* coefficient in model (9) is significant at a 6% level, which essentially does not reduce the reliability of the obtained estimates. One of the tests revealed signs of heteroscedasticity in model (9), but an additional White's test (BP_{wt}) indicates its absence. The second cluster models have been verified using the Chow test; satisfactory results were obtained for both equations, which indicates the calculated dependences are stable.

Since for the second group of countries the investments' share in GDP is 21.8%, the TF calculation for

Figure 1. **Sliding Correlation Coefficients between Indicators D and P**



Source: author.

models (8) and (9) yielded the value P*=71.7%. That is, for the "catching-up" countries, the TF identification problem is highly relevant. In their case the learning and increased cost effects are classic, while the supply and demand curves (8) and (9) are multidirectional (Figure 3). Furthermore, the resulting value implies that developing economies face a serious innovation barrier. Accordingly, before starting to implement R&D projects they will have to achieve labor productivity of at least two-thirds of the US level, among other things by borrowing and applying foreign technologies. Only then would launching national initiatives to develop domestic innovations would make sense.

There are two interesting and unexpected aspects about the obtained results.

The first is increase in the TF over time. In our previous work [*Balatsky*, 2012], the TF was "roughly" estimated at 61.5%, while the above "fresher" calculations resulted in a value of 71.7%, i.e., 10 pp more. If we do not write the resulting discrepancies off to the nuances of the algorithms applied to obtain the two estimates, it can be assumed that switching to an active innovation policy is harder for "late start" countries. The "borrowing trap" becomes increasingly deeper and stronger: belated economies are forced to keep using foreign technologies for a long time. To break out of this trap one must not just reduce the gap with the leader but come very close to them in terms of labor productivity.

The second factor (which decreases the TF value) is investment activity. Calculations show that an increase in fixed asset investment from 21% to 30% allows one to reduce the TF from 71.7% to 47.5%. Therefore, the technology borrowing trap does not look fatal. If catching-up countries want to overcome it, they must deliberately abandon the consumer mindset for a while in favor of high investment activity. The USSR, South Korea, and China pursued similar strategies in their time. Otherwise, the catching-up period can last indefinitely.

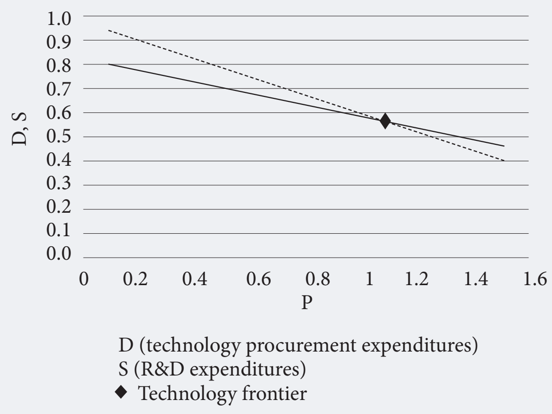
Successful and Unsuccessful Strategies to Overcome the TF

Taking TF into account is very important for catching-up countries since it helps them avoid two types of mistakes: insufficient innovation activity in relation to overall economic potential and its premature build-up in the absence of an adequate basis. Delays in creating a national innovation system when the necessary technological prerequisites are in place would be just as disastrous as attempts to set one up in the absence of a solid economic foundation. Many countries have experience of mistakes and achievements in this field. Below the contrasting roles of TF in innovation policy are illustrated using the examples of South Korea, China, and Russia.

China

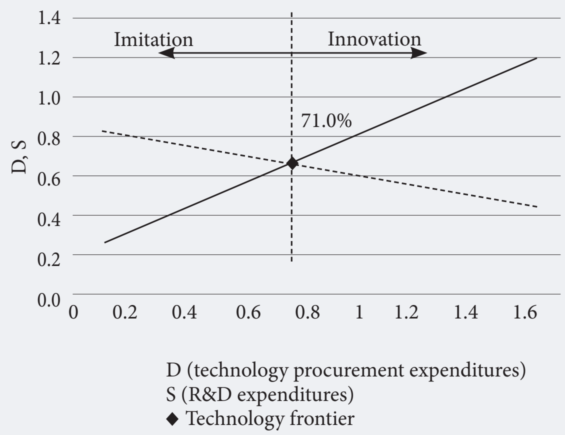
Back in the 1980s the archaic Chinese economy could not claim a decent technological level. Local businesses started by imitating and slightly improving foreign products [*Yip, McKern*, 2016]. Later a policy of integrating Chinese companies into transnational ICT value chains was introduced. Cooperation with Intel, Google, and MediaTek created the prerequisites for major technological diffusion and promot-

Figure 2. **Know-How Supply and Demand Curves for the Advanced Countries Group**



Source: author.

Figure 3. **Know-How Supply and Demand Curves for the Catching-up Countries Group**



Source: author.

ed the emergence of domestic enterprises producing high-tech products under Chinese brands. Since 2004, they have created innovations and stepped up R&D [*König et al.,* 2018]; the domestic generation of new technologies has become a systemic process. Since the TF has not yet been reached, innovation has not become large-scale. However, the steady growth of R&D expenditures as a share of GDP helps the country to confidently progress towards this mark (Table 1). The imitation strategy supplemented by domestic innovations yielded impressive results: in 2018, nine Chinese companies specializing in advanced industries have joined the world's top 100 in terms of R&D expenditures.[4]

South Korea

South Korea's technological development path can be notionally divided into four stages [*El Fakir,* 2008]. During the first two the country actively acquired foreign technologies. In 1962-1982 more than 2,000 purchase contracts were completed, whose total value amounted to almost half of all direct investments made during that period [*Suh, Chen Derek,* 2007]. Protectionist measures to support local corporations (*chaebols*) were also seen as acceptable [*Lee et al.,* 1996]. At the third stage (1980–1990s), the transition to innovations began. As a result, the amount of internal R&D increased and high-tech companies emerged. The fourth stage (which began in the late 1990s) is characterized by a cluster approach to managing the development of national industry and supporting corporations — world leaders. To this end, the country was divided into zones corresponding to their core industries; innovation is promoted taking into account the specific characteristics of each zone [*Kim,* 2008]. Currently South Korea is close to the TF (Table 1) and has radically increased internal R&D expenditures. In 2018 four Korean companies were among the global leaders in terms of their R&D spending.[5]

Thus, thanks to a consistent innovation policy, South Korea and China have moved from borrowing foreign technologies to creating innovations in a limited number of prospective industries (high-tech clusters). The factor of maturity is being taken into account: being aware that the TF has not yet been overcome, neither government has striven to cover the entire high technology market.

Russia

Since the beginning of major economic reforms in 1992 Russia has adopted numerous strategic documents aimed at promoting innovation. However, no real progress has been made in stepping up the technological level of production. Possible reasons include specific macroeconomic conditions, market structure, and corporate governance, i.e. an institutional system which does not meet the requirements for innovation-based development [*Gokhberg, Kuznetsova,* 2009] and excessive reliance on state corporations [*Simachev et al.,* 2014]. In our opinion, the main factor explaining the failure of all plans to create a high-tech sector were the attempts to "leapfrog" the imitation stage straight into innovation development. As a result, Russia was unable to noticeably improve its global position in labor productivity and remains far removed from the TF (Table 1).

[4] https://www.strategyand.pwc.com/innovation1000#VisualTabs1, accessed on 21.06.2021.

[5] https://www.strategyand.pwc.com/innovation1000#VisualTabs1, accessed on 21.06.2021.

In addition, numerous internal and external innovations turned out to be unwanted by Russian businesses: the companies needed simple but more productive technologies, while the developers offered sophisticated and untested solutions. This inconsistent policy has led to stagnation in R&D expenditures and the absence of global leaders among national high-tech companies. In the 2018 ranking of companies – the largest R&D spenders – only Gazprom was included (448th place). Without focusing on the tactical mistakes of the national innovation policy, it would hardly be an exaggeration to say that the main problem with modernizing the economy is the absence of internal and external mechanisms for technological dissemination. Even the practices of successful domestic enterprises are still not being adopted by companies specializing in similar areas. External borrowing mechanisms are not fully mature and their application is significantly hindered by international sanctions.

Table 1. **Labor Productivity in Selected Countries Relative to the US Level (PPP), %**

Year	China	Souch Korea	Russia
1975	n/a	9.4*	n/a
1985	1.5*	16.5*	n/a
1992	4.1	37.8	43.9
1995	5.5	43.4	35.8
2000	7.0	48.2	34.1
2005	9.9	51.0	39.4
2010	15.6	57.3	43.4
2015	21.7	59.3	45.2
2017	24.5	61.4	46.0

* Not counting PPP.
Source: author.

Discussion of Results

The interpretation of TF and the algorithm for its quantitative assessment presented above contribute to the set of useful analytical tools applied in economics. Taking this indicator into account provides a number of advantages. Identifying the TF allows one to very accurately determine the "club" a particular country belongs to. If the actual relative labor productivity is much lower than the TF, we are talking about a technologically backward economy; otherwise, an economy it can be classified as a leader. The hypothesis that for technologically advanced countries the very concept of TF as a threshold value is meaningless since they have already reached the innovation development stage was confirmed. On the contrary, for catching-up economies, the TF very much remains important for determining their place in the global system.

Understanding a country's position in relation to the TF allows one to determine which type of technology policy should be the priority: borrowing innovations or creating them. The country examples given in the previous section show that taking this into account helps shape an adequate technology policy and accelerate economic modernization. At the same time, ignoring the existing technological barrier leads to the disorientation of the authorities, unbalanced research and production strategy, chaotic experimentation with various innovation promotion institutions, and setting incorrect priorities for funding and organizing production.

A number of features do not allow for using the TF automatically, in a standardized way. Its content and identification algorithm require careful handling. TF assessments cannot be seen as absolute since the econometric apparatus, despite its potential, does not guarantee the high accuracy of such a complex indicator. In our opinion the actual TF value lies within the ± 3 pp range from the identified one.

The TF we have defined is macroeconomic in nature. At the same time, in many countries including Russia labor productivity in different industries can vary drastically, and individual companies' performance in the same industry in different regions – by even more dramatic measures [*Balatsky, Ekimova,* 2020]. Therefore, a TF macro-estimate provides only a general benchmark for shaping technology policy for the economy. Sectoral and regional analyses will allow one to identify the zones where it would make more sense to borrow technologies or create them on one's own. Ideally, the TF should be identified for each industry individually, to ensure the source data is comparable. However, at present there is no statistical basis for this, so one could at least follow a general rule regarding the critical TFP value.

The proposed theoretical structure is extremely simplified, so it uses "pure" strategies: borrowing new technologies vs developing them. In reality, many countries adopt mixed strategies, when in certain more backward economic segments the borrowing mode is applied while in others one's own innovations are developed, which by definition disproves assumptions regarding the binary nature of economic and technological policies. Thus, the TF indicates the dominant modernization model, while breaking zones down into two modes is the prerogative of a more thorough analysis of the national economy and its technological level.

Even an extremely correct identification of the TF for the entire economy or a particular sector does not tell exactly which mechanisms should be applied for borrowing or creating innovations. Designing such tools seems to be an art and depends upon the competency level of the government authorities. In other words, the TF allows for helping one understand how technological progress should be made at a qualitative level: mainly by imitating or creating one's own innovations.

The above allows the authors to suggest a thesis about the suitability of using the TF concept in Russian innovation policy, taking into account the previously noted nuances and limitations. At the same time our calculations show that the borrowing of new technologies was extremely ineffective in Russia. Distance to the TF and the rate of approaching it can be used as effectiveness criteria. Thus in 2017 South Korea was just 10 pp away from the TF, while Russia was more than 25. South Korea's rate of advancing towards the TF in 1992-2017 was 11.2 times higher than Russia's. In recent years the situation in Russia has improved, but it is still far from being perfect (Table 1). The above criteria were even more striking in manufacturing industries, where labor productivity in Russia in relation to the US was 16.7% and in South Korea — 71.2% (the TF level!).[6] This state of affairs is also confirmed by the rate of industrial robots procurement: according to the International Federation of Robotics, the density of industrial robots in South Korea in 2018 was 774 units (per 10,000 employed), and in Russia only five.[7]

The country's official documents on S&T development do not set the objective of organizing a systemic, planned borrowing of foreign technologies and the application of domestic ones. Meanwhile this is what TF identification is focused on. Here Russia has an underutilized regulatory reserve for modernizing the economy and potential for the fruitful application of the new indicator.[8]

Conclusion

The presented constructs show that the Schumpeterian analysis of the innovative sphere still remains constructive and can produce new interesting results. Applying the TF concept in its narrow interpretation as the threshold TFP value allows one to significantly advance Schumpeter's concept about the two technological development phases: imitation (borrowing) and innovation (creation) of technologies [Schumpeter, 1964]. For catching-up economies including Russia, an effective transition from one development phase to the other implies observing specific laws and conditions. One of them is that the developing country must reach the TF; failure to follow this principle leads to inefficient expenditures and hinders development.

Despite the simplicity of the TF concept, in practice it can be unintentionally breached for various reasons. After the collapse of the USSR and the loss of its industrial potential, Russia moved into the catching-up category but due to institutional inertia, no effective mechanisms for large-scale technology borrowing have been created over the past three decades. The country is not unique in this respect: many nations are trying to gain independence and international credence by promoting their R&D sector despite the national economy's inadequate technological level. This group of countries seems to include Pakistan, Iran, and Nigeria. Such strategies not only obstruct development, but also provoke various economic imbalances and social tensions.

This paper was prepared in the framework of the state assignment by the Government of the Russian Federation to the Financial University for 2021 on the topic "Technological, structural, and social factors of long-term economic growth". The author would like to express their sincere gratitude to the anonymous reviewers for helpful comments on the manuscript.

References

Balatsky E.V. (2012) Technological Diffusion and Investment Decision. *Journal of the New Economic Association*, 15(3), 10–34 (in Russ.).

Balatsky E.V., Ekimova N.A. (2020) Internal Sources of Labour Productivity Growth in Russia. *World of the New Economy*, 14(2), 32–43. https://doi.org/10.26794/2220-6469-2020-14-2-32-43 (in Russ.).

Bessonova E.V. (2007) Evaluation of production efficiency of Russian industrial enterprises. *Applied Econometrics*, 2, 13–35 (in Russ.).

Dementiev V.E. (2006) Trap of the Technological Dependence and Condition of Its Overcoming in Two-Sector Model of Economy. *Economics and Mathematical Methods*, 42(4), 17–32 (in Russ.).

Gokhberg L.M., Kuznetsova I.A. (2009) Innovation in the Russian economy: Stagnation before the crisis? *Foresight-Russia*, 3(2), 28–46 (in Russ.).

Polterovich V.M. (2009) The Problem of Creating a National Innovation System. *Economics and Mathematical Methods*, 45(2), 3–18 (in Russ.).

[6] Gross value-added statistics were used in the calculations (http://data.un.org/Data.aspx?q=Gross+Value+Added+by+Kind+of+Economic+Activity&d=SNAAMA&f=grID%3a202%3bcurrID%3aUSD%3bpcFlag%3a0, accessed on 21.06.2021.), and employment data (https://www.ilo.org/shinyapps/bulkexplorer29/?lang=en&segment=indicator&id=EMP_TEMP_SEX_ECO_NB_A, accessed on 21.06.2021.)

[7] https://roscongress.org/en/materials/perspektivnye-napravleniya-primeneniya-robototekhniki-v-bisnese/, accessed on 21.06.2021.

[8] There are various borrowing mechanisms: introducing tax incentives for foreign companies operating in the country, encouraging domestic enterprises to purchase and apply advanced equipment by deducting the amount of relevant investments from profits, etc. However, this practical issue deserves a separate discussion and goes beyond the scope of our paper, which is predominantly instrumental in nature.

Simachev Yu.V., Kuzyk M.G., Feigina V.V. (2014) State support for innovation in Russia: What can be said about the impact of tax and financial mechanisms on companies? *Russian Management Journal*, 12(1), 7–38 (in Russ.).

Yasin E.G., Snegovaya M.V. (2018) The Role of Innovations in the World Economic Development. *Voprosy Ekonomiki*, 9, 15–31. https://doi.org/10.32609/0042-8736-2009-9-15-31 (in Russ.).

Acemoglu D. (1997) Training and innovation in an imperfect labour market. *The Review of Economic Studies*, 64(3), 445–464. https://doi.org/10.2307/2971723

Acemoglu D., Aghion P., Zilibotti F. (2003) Vertical integration and distance to frontier. *Journal of the European Economic Association*, 1(2–3), 630–638. https://doi.org/10.1162/154247603322391260

Acemoglu D., Aghion P., Zilibotti F. (2006) Distance to frontier, selection, and economic growth. *Journal of the European Economic Association*, 4(1), 37–74. https://doi.org/10.1162/jeea.2006.4.1.37

Aghion P., Howitt P., Mayer-Foulkes D. (2005) The effect of financial development on convergence: Theory and evidence. *The Quarterly Journal of Economics*, 120(1), 173–222. https://doi.org/10.1162/0033553053327515

Aigner D., Lovell C., Schmidt P. (1977) Formulation and Estimation of Stochastic Frontier Production Function Models. *Journal of Econometrics*, 6(1), 21–37. https://doi.org/10.1016/0304-4076(77)90052-5

Alder S. (2010) Competition and innovation: Does the distance to the technology frontier matter? *SSRN Electronic Journal*, June 1. http://dx.doi.org/10.2139/ssrn.1635789

Andrade L.R., Cardenas L.Q., Lopes F.D., Oliveira F.P.S., Fernandes K.C. (2018) The Impact of R&D Investments on Performance of Firms in Different Degrees of Proximity to the Technological Frontier. *Economics Bulletin*, 38(2), 1156–1170.

Baldwin W.L., Childs G.L. (1969) The fast second and rivalry in research and development. *Southern Economic Journal,* 36(1), 18–24. https://doi.org/10.2307/1056804

Battisti M., Del Gatto M., Parmeter C.F. (2018) Labour productivity growth: Disentangling technology and capital accumulation. *Journal of Economic Growth*, 23(1), 111–143. https://doi.org/10.1007/s10887-017-9143-1

Benhabib J., Perla J., Tonetti C. (2017) *Reconciling models of diffusion and innovation: A theory of the productivity distribution and technology frontier* (NBER Working Paper w23095), Cambridge, MA: National Bureau of Economic Research.

Caselli F., Coleman I.I., John W. (2006) The world technology frontier. *American Economic Review*, 96(3), 499–522. DOI: 10.1257/aer.96.3.499

Cincera M., van Pottelsberghe de la Potterie B. (2001) International R&D Spillovers: A Survey. BrusselsBrussels: Université libre de Bruxelles.

Cirera X., Fattal Jaef R.N., Maemir H.B. (2017) *Taxing the good? Distortions, misallocation, and productivity in Sub-Saharan Africa*, Washington, D.C.: The World Bank. http://documents.worldbank.org/curated/en/492891485178180375/Taxing-the-good-distortions-misallocation-and-productivity-in-Sub-Saharan-Africa, accessed 15.02.2020.

Coad A. (2008) *Distance to frontier and appropriate business strategy* (DRUID Working Paper 0807), Copenhagen: Copenhagen Business School. https://www.econstor.eu/bitstream/10419/31801/1/572410638.pdf, accessed 15.02.2020.

El Fakir A. (2008) South Korean system of innovation: From imitation to frontiers of technology, successes and limitations. In: *Management of Technology Innovation and Value Creation. Selected Papers from the 16th International Conference on Management of Technology* (eds. M.H. Sherif, T.M. Khalil), pp. 275–292. https://doi.org/10.1142/9789812790545_0017

Farrell M.J. (1957) The Measurement of Productive Efficiency. *Journal of the Royal Statistical Society. Series A (General)*, 120(3), 253–290. https://doi.org/10.2307/2343100

Filippetti A., Peyrache A. (2017) Productivity growth and catching up: A technology gap explanation. *International Review of Applied Economics*, 31(3), 283–303. https://doi.org/10.1080/02692171.2016.1249831

Gombau V., Segarra A. (2011) *The Innovation and Imitation Dichotomy in Spanish Firms: Do Absorptive Capacity and the Technological Frontier Matter?* (XREAP Working Paper 2011-22). https://papers.ssrn.com/sol3/papers.cfm?abstract_id=1973790, accessed 15.02.2020.

Gouveia A.F., Santos S., Goncalves I. (2017) *The impact of structural reforms on productivity: The role of the distance to the technological frontier* (OECD Productivity working paper № 8), Paris: OECD. https://www.oecd-ilibrary.org/economics/the-impact-of-structural-reforms-on-productivity_6e4a4bf7-en;jsessionid=ocD4z8zimAYXeuT-JLPtgBRG.ip-10-240-5-160, accessed 15.02.2020.

Kim Y.S. (2008) Regional Industrial Policy in Korea – Its Outcomes and Implications. *KIET Industrial Economic Review*, 2, 17–26.

König M., Storesletten K., Song Z., Zilibotti F. (2018) *From Imitation to Innovation? Where Is All That Chinese R&D Going?*, New Haven, CO: Yale University. https://economics.stanford.edu/sites/g/files/sbiybj9386/f/kssz_180403_webpage.pdf, accessed 15.02.2020.

Lee M., Son B., Om K. (1996) Evaluation of national R&D projects in Korea. *Research Policy,* 25(5), 805–818. https://doi.org/10.1016/0048-7333(96)00879-7

No J.Y.A., Seo B. (2014) Innovation and Competition. *Korea and the World Economy,* 15(2), 155–183.

Paulson Gjerde K.A., Slotnick S.A., Sobel M.J. (2002) New product innovation with multiple features and technology constraints. *Management Science*, 48(10), 1268–1284. https://doi.org/10.1287/mnsc.48.10.1268.270

Polterovich V., Tonis A. (2005) *Innovation and Imitation at Various Stages of Development: A Model with Capital* (NES Working Paper). https://papers.ssrn.com/sol3/papers.cfm?abstract_id=1753531, accessed 15.02.2020.

Rabe C. (2016) Capital controls, competitive depreciation, and the technological frontier. *Journal of International Money and Finance*, 68, 74–102. https://doi.org/10.1016/j.jimonfin.2016.06.003

Sala-i-Martin X.X., Barro R.J. (1995) Technological diffusion, convergence, and growth (Center Discussion Paper 735). https://www.econstor.eu/bitstream/10419/160652/1/cdp735.pdf, accessed 15.02.2020.

Sato K. (1974) The neoclassical postulate and the technology frontier in capital theory. *The Quarterly Journal of Economics*, 88(3), 353–384. https://doi.org/10.2307/1881941

Scherer F.M. (1967) Research and development resource allocation under rivalry. *The Quarterly Journal of Economics*, 81(3), 359–394. https://doi.org/10.2307/1884807

Schewe G. (1996) Imitation as a strategic option for external acquisition of technology. *Journal of Engineering and Technology Management*, 13(1), 55–82. https://doi.org/10.1016/0923-4748(96)00005-7

Schumpeter J.A. (1964) *Business Cycles: A Theoretical, Historical and Statistical Analysis of the Capitalist Process*, New York: McGraw-Hill

Segerstrom P.S. (1991) Innovation, imitation, and economic growth. *Journal of Political Economy*, 99(4), 807–827. http://dx.doi.org/10.1086/261779

Slivko O., Theilen B. (2014) Innovation or imitation? The effect of spillovers and competitive pressure on firms' R&D strategy choice. *Journal of Economics,* 112(3), 253–282. https://doi.org/10.1007/s00712-013-0361-5

Solow R.M. (1956) A contribution to the theory of economic growth. *The Quarterly Journal of Economics*, 70(1), 65–94. https://doi.org/10.2307/1884513

Song B.J., Lim D. (2006) Korean Industry Vision 2020 and Megatrends. *KIET Industrial Economic Review*, 1, p. 8.

Suh J., Chen Derek H.C. (2007) *Korea as a Knowledge Economy: Evolutionary Process and Lessons Learned*, Washington, D.C.: World Bank Institute, Korea Development Institute.

UNCTAD (2018) *The Technology and Innovation Report 2018: Harnessing Frontier Technologies for Sustainable Development*, Geneva: UNCTAD. https://unctad.org/en/PublicationsLibrary/tir2018_en.pdf, accessed 15.02.2020.

Yip G.S., McKern B. (2016) *China's next strategic advantage: From imitation to innovation,* Cambridge, MA: MIT Press.

Green Digitalization in the Electric Power Industry

Julia Turovets
Expert, Digital Economics Centre, yturovecz@hse.ru

Liliana Proskuryakova
Deputy Laboratory Head, Laboratory for Science and Technology Studies, lproskuryakova@hse.ru

Anna Starodubtseva
Research Assistant, Laboratory for Science and Technology Studies, astarodubtseva@hse.ru

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

Vincenzo Bianco
Associate Professor, vincenzo.bianco@unige.it

Genova University, Via All'Opera Pia 15/A, 16145 Genova, Italy

Abstract

The lasting global economic downturn caused by the COVID-19 pandemic allows decision-makers and societies to re-think the basis and drivers of economic growth, laying the foundation for sustainable development. The green economic recovery can take place with a leading role played by the energy industry. This paper focuses on the application and desired effects of green digital technologies in the electric power industry in ten countries — the largest electricity producers and consumers. This study is designed in the framework of the sectoral innovation systems concept. The research tasks were addressed first through horizon scanning (the analysis of research and analytical publications). Second, the green digitalization indicators for the electric power industry in the selected countries were identified with the use of statistical and other available reliable data and compared. Third, a comparative analysis of national strategic documents was performed, along with corporate tasks and indicators that reflect the digital transformation at micro level. As a result of this study, key trends and three models of green digitalization at the national level were identified, the prerequisites and potential social and economic effects of the application of these technologies in electric power industry were described.

Keywords: digital technologies; green technologies; energy industry; sustainable development; economic recovery; Internet of Energy; smart grid

Citation: Turovets J., Proskuryakova L., Starodubtseva A., Bianco V. (2021) Green Digitalization in the Electric Power Industry. *Foresight and STI Governance*, 15(3), 35–51. DOI: 10.17323/2500-2597.2021.3.35.51

Introduction

The protracted global economic downturn caused by the COVID-19 pandemic is changing the understanding of growth sources and the drivers that determine the long-term reduction in adverse effects on the environment and climate. The digitalization of various industries which began even before the pandemic appreciably accelerated in 2020 and became a major trend contributing to increased technological and economic efficiency, labor productivity, more accurate planning, a reduced accident rate, and the promotion of green growth [*Midttun, Piccini,* 2017; IEA, 2020b; *Montevecchi et al.,* 2020].

The fuel and energy sector plays an important role in the green post-crisis economic recovery [*Barbier,* 2020; *Noussan et al.,* 2021]. Given the growing demand for electricity and the specifics of the sector's development, the electric power industry is of particular importance [IEA, 2020a; IRENA, 2019]. For the decade of 2016-2025, the potential growth of value-added due to digitalization is estimated at $1.3 trillion [WEF, 2016]. Like other segments of the fuel and energy sector, the electric power industry is affected by a number of trends:

- accelerated growth in generation from and investments in renewable energy sources (RES);
- the promotion of energy saving and energy efficiency against the background of a growing demand for energy resources;
- restructuring of producer-consumer relations due to the emergence of smart grids and the internet of energy.

The growing share of electricity in the global energy balance allows one to assess the prospects for related markets. Cutting-edge technologies, such as digital substations, increase the efficiency of generation, reduce transmission losses (especially over long distances), and optimize energy flows. Digital energy consumption management based on the use of smart meters reduces the load during peak hours and the costs for various consumer groups.

The proliferation of inexpensive, reliable, and environmentally friendly energy sources in many countries is associated with supplying energy-poor regions with "clean" electricity from local renewable sources and the construction of smart mini- and micro-grids.[1] The active introduction of distributed, autonomous, and individual generation is also taking place in Russia. Many companies are switching to in-house generation: their share in the total electricity output exceeded 5% in 2018 and continues to grow at about 3% per year[2] [Russian Ministry of Energy, 2019]. This trend is facilitated by the development of high-capacity energy storage technologies and the reduction of their costs, along with reduced costs of rooftop solar panels and solar-wind installations for personal use. The emerging risks for Russia are associated with the planning and construction of generation facilities, especially given the existing surplus capacity.

Digitalization strategies for the fuel and energy sector, first of all the electric power industry, play a key role in the global proliferation of the green economy due to increased resource efficiency and the expansion of clean energy sources. No generally accepted understanding of this process in relation to traditional industries has yet emerged in the literature [OECD, 2019a]. The existing studies only emphasize the need for an integrated approach to considering its features at various levels [IEA, 2017; OECD, 2019b].

The sectoral innovation systems concept, widely applied to studying the use of technologies in various sectors [*Malerba,* 2002], served as the theoretical basis of this study. The key characteristics and effects of applying green digital technologies in the electricity transmission and distribution segment are examined, at the national and sectoral levels. A comparative analysis of the industry's transformation in ten countries – the leaders in electricity generation – was conducted (China, the US, India, Russia, Japan, Canada, Germany, Brazil, South Korea, and France). Three models of the digital transformation in the electric power industry at the national level are proposed and the main effects of this process are assessed.

Main Areas of Green Digitalization in the Electric Power Industry

The digitalization of traditional sectors of the economy is a relatively new vector of research, with a growing number of scientific and analytical publications [*Beier et al.,* 2017; *Müller et al.,* 2018; *Teece,* 2018]. This topic is addressed in the framework of broader concepts and phenomena, such as Industry 4.0, smart manufacturing, the internet of things (IoT), cyber-physical systems, and platform economy [*Kang et al.,* 2016; *Ghobakhloo,* 2018; *Kamble et al.,* 2018]. Digital technologies' effects are very much specific to various economies, industries, and countries due to the infrastructural nature of the industry, its major economic and social consequences, and growing demand from emerging industries, in particular the data storage and processing segment [*Gatto, Drago,* 2020; *Tripathi, Kaur,* 2020]. The development of the electric power industry is also affected by regulatory constraints caused by global environmental challenges [*Newberry,* 2001; *Cavanagh,* 2021].

Digitalization helps optimize the operation and maintenance of power grids. New services are emerging, energy trading is being automated. Renewable energy systems are being decentralized [*Graf, Jacobsen,* 2021; BDEW, 2019]. Smart (actively adaptive) networks and

[1] https://www.un.org/sustainabledevelopment/ru/energy/, accessed on 28.03.2021.

[2] https://minenergo.gov.ru/node/532, accessed on 19.02.2021.

sensors, the internet of energy, virtual power plants, digital substations, distributed ledger systems (blockchain), and digital platforms are gaining popularity [*Dellermann et al.,* 2017; *Ketter et al.,* 2018; *Adeyemi et al.,* 2020; *Menzel, Teubner,* 2020]. Each of the above areas use a specific set of technologies [KAS, 2020]. Smart grids integrate various devices used by energy producers, suppliers, and consumers [*Ketter et al.,* 2018; *Bertolini et al.,* 2020]. Smart meters are at their core: they monitor consumption in real time and transmit data to the supplier to help make decisions about infrastructure optimization, and thus manage energy consumption [*Waite et al.,* 2017; *Ketter et al.,* 2018]. Smart devices also include sensors for monitoring the electricity quality [*Bagdadee et al.,* 2020], power transmission losses [*Song et al.,* 2017], the state of underground infrastructure [*Rodríguez et al.,* 2020], automating system management [*Wertani et al.,* 2020], monitoring the condition of equipment [*Dileep,* 2020], and so on.

Blockchain technologies are finding wide application in creating secure digital environments [*Carvalho,* 2015; *Adeyemi et al.,* 2020; *Zhu et al.,* 2020]. Such systems monitor operational processes (e.g., the operation of devices which control the power grid voltage), identify deviances, and prevent interruptions in supply and unforeseen situations [*Shahidehpour, Fotuhi-Friuzabad,* 2016]. Participants' interactions are facilitated by smart contracts which make transactions secure and allow one to manage digital assets (tokens), bill, identify parties, and provide access using modern encryption algorithms [*Andoni et al.,* 2019; *Adeyemi et al.,* 2020]. In new segments of the electric power industry, first of all RES, distributed ledger technologies are applied to monitor the entire value chain. Consumers can sell surplus electricity they generate (the prosumer concept) [*Zhu et al.,* 2020]. Cryptocurrencies (SolarCoin, EverGreenCoin, EcoCoin, EECoin, NRGcoin [*Andoni et al.,* 2019]) reduce the role of intermediaries in electricity supply. So far such projects remain in pilot mode [*Adeyemi et al.,* 2020]. Carbon dioxide emission quotas can also be traded, which is especially important against the background of increasingly strict climate-related regulations [*Andoni et al.,* 2019]. The RES infrastructure includes virtual power plants which ensure a stable level of total generation and supply. It is an operator-controlled system of small generating facilities linked by open interfaces [*Dellermann et al.,* 2017].

Digital platforms reduce the risks for individual participants and provide personalized services for them. There are electricity platforms which connect retailers and consumers (B2C), or customers with each other (C2C); plug-sharing platforms; electric and hybrid vehicle charging devices able to return surplus energy back to the network (vehicle-to-grid, V2G), etc. They can flexibly manage the network load. Operators regulate participants' activities, whose roles can change. For example, a utility company can act on different platforms as electricity seller, buyer, or service provider [*Menzel, Teubner,* 2020].

The industry digitalization's drawbacks include increased requirements for information security, the need to attract significant capital investments with a long payback period, and problems with integrating new devices into the existing infrastructure [*Edelstein, Kilian,* 2007]. Technological innovation and consumer involvement in demand management require new digital competencies. The pace of digitalization is largely determined by the quality of regulation and market maturity, including the security of data storage and exchange systems and the compatibility of information systems and equipment [*Epiphaniou et al.,* 2020; *Anderson, El Gamal,* 2017; European Commission, 2017].

The legal frameworks for and the principles of involving consumers in energy trade are becoming a new management area. Industry standards for applying advanced technologies are being developed [*Afanasyev et al.,* 2019]. Establishing the rules for processing and storing large amounts of data by industry organizations requires a special effort [*Adeyemi et al.,* 2020]. Digitalization will increase companies' productivity. According to certain forecasts, ignoring this process will lead to every fourth electricity supplier going bankrupt by 2025 [*Schwieters et al.,* 2016; *Menzel, Teubner,* 2020]. Digital technology platforms can change the investment model's focus from a limited number of large programs to a portfolio of small consumer-initiated projects [*Menzel, Teubner,* 2020]. The scale of the labor market transformation caused by the introduction of digital technologies will be comparable to the impact of liberalization and job cuts. For example, during the reform period of 1998-2007, the number of jobs in the German electric power sector decreased by 20% [*Graf, Jacobsen,* 2021].

Approaches to studying the digital transformation in various industries are still being developed. A range of quantitative and qualitative analysis techniques are being tested [European Commission, 2019b; *Zaoui, Souissi,* 2020]. Most of the research is focused on the application of specific digital technologies and their technical and economic parameters [*Ketter et al.,* 2018; *Xiong et al.,* 2018; *Adeyemi et al.,* 2020; *Ahmad et al.,* 2021; *Bagdadee et al.,* 2020; *Bertolini et al.,* 2020; *Dileep,* 2020] as well as institutional restructuring at the sectoral and national levels [*Dellermann et al.,* 2017; *Menzel, Teubner,* 2020; *Graf, Jabobsen,* 2021]. Few studies compared the various aspects and effects of digitalization. This paper fills the gap by summarizing the trends, challenges, and effective solutions for the green digital transformation of the electric power industry.

Methodology and Design of the Study

The research toolkit is comprised of horizon scanning, case studies, expert interviews, company executive surveys, and collating available statistics. The analysis of scientific publications and predictive analytical materials issued by international organizations and the world's leading think tanks in 2017–2020 allowed the authors to identify promising areas for the industry's green digitalization.[3]

A comparative analysis of ten countries' — the world's largest producers and consumers of electricity — strategies was carried out to study national digitalization initiatives: China, the US, India, Russia, Japan, Canada, Germany, Brazil, South Korea, and France. The data was structured as follows: country; the title of the policy document describing measures to encourage the application of digital technologies in the industry; key national-level development areas in the sector and the tools used to support digitalization. Using theoretical and practical approaches [*Brown, Brown,* 2019; *Korachi, Bounabat,* 2019; *Lichtenthaler,* 2020], the stages of the digital transformation in the industry were identified, the progress in implementing them in the sample countries described, and a list of the main quantitative indicators drafted. Data sources included the World Bank [World Bank, 2021], the US Energy Information Administration [DOE, 2021], the Statista [Statista, 2021a,b,c] and Autostat[4] portals, and various scientific and analytical publications.

The suggested approach contributes to comparative studies of the digitalization of electric power industry and can be applied to other segments of the fuel and energy sector.

Green Digitalization as a Priority

Governments not only encourage digitalization but take steps to diminish its possible negative effects such as job cuts [*Graf, Jacobsen,* 2021], the emergence of more complex management systems [*Ahl et al.,* 2020], data security threats [*Dellerman et al.,* 2017], an increased regulatory burden on companies, and ambiguous legal frameworks [*Soshinskaya et al.,* 2014]. Large economies, the leaders in the absolute electricity generation output, were included in the sample (Table 1).

For each country, the available industry policy documents were analyzed (published mainly in 2015–2020). Development strategies, analytical materials on technical, economic, and technological matters, legislation regulating the introduction and application of specific technologies, the adoption of tariffs, and so on were reviewed. Key digitalization characteristics and government policy tools were identified.

In most economies smart grids are at the core of the digital transformation. The introduction of other technologies (IoT, artificial intelligence (AI), cloud technologies, digital twins, etc.) is usually planned in national digitalization strategies which are cross-cutting in nature, i.e., they cover a wide range of industries. In some countries including Russia the digitalization strategy for the electric power industry is presented in a separate document.

China remains the world's largest energy consumer and clean energy producer (30% share in total generation). Investments are primarily channeled to adapt the network infrastructure for RES, increase conventional power plants' flexibility, manage demand, and develop large-scale energy storage systems. The rapidly growing Chinese electric vehicle market has good prospects for integration into the national energy system. Due to rapidly growing energy consumption, the planned transition to clean energy and carbon neutrality by 2060 will likely remain unaccomplished. This scenario can be avoided by implementing and scaling up all possible digitalization tools [IEA, 2019a].

In the next decade the US will remain among the largest electricity consumers and producers. Gas-based generation will continue to dominate, while the RES share will continue growing and coal-based generation will significantly decrease. Power plants and power systems of all types will have to dramatically improve their productivity through digitalization, efficient resource management, lean production, and the introduction of advanced big data analytical systems. Work process optimization, digitalization, and agile working will help utility companies increase productivity by 3% and reduce electricity production costs (excluding fuel) by 10%-20% for coal power plants and by 5%-15% for gas ones, with improved safety [McKinsey & Company, 2019]. The main risks are associated with the loss of jobs, lack of qualified personnel to fill the newly created digital vacancies in the energy sector, and ensuring adequate cybersecurity at the achieved digitalization level. As in Canada, the US regions have significant autonomy in choosing core generation and digitalization technologies, which hinders their integration.

If India maintains its current economic growth rates, in a few years' time it will become the world's biggest energy consumer overtaking China. So far, the main energy sources in the country have been coal and oil; over 80% of the latter is imported. To meet the demand and reduce import dependence, solar generation is being rapidly promoted and integrated into the grid through digitalization. National priorities are focused on digitalizing the networks (monitoring transient processes, AC power transmission, etc.) and power distribution systems (based on advanced control systems such as SCADA, ADMS, etc.), automating and designing digital substations (there were

[3] The publications were selected using the following keywords: digitization, digital transformation, digital/smart energy, energy power industry; smart meters, internet of energy, energy blockchain platform; green/distributed/renewable energy.

[4] https://www.autostat.ru/news/42999/, accessed on 19.02.2021.

Table 1. **Top Electricity Producers in 2019 and a Forecast for 2030**

Country	Electricity production in 2019, TW	Ranking position (2019)	Electricity production in 2030, TW	
			Baseline scenario	Energy transition scenario
China	7 482	1	9 952	9 317
US	4 385	2	4 506	4 153
India	1 614	3	2 461	2 365
Russia	1 122	4	1 207	1 146
Japan	1 013	5	1 001	958
Canada	649	6	690.7	—
Germany	616	7	—	—
Brazil	615	8	770	711
South Korea	576	9	—	—
France	570	10	—	—

Source: authors, based on [Enerdata, 2020; IEA, 2020f; IRENA, 2020].

more than 50 of them in the country in 2019), and supporting prosumers and active consumers [*Batra,* 2019]. The main constraints are associated with high levels of poverty and the rapidly growing economy's dependence on imported oil.

In Russia, with its predominantly gas-fired TPPs, RES account for less than 1% of centralized energy generation. The industry-related initiatives are incorporated in the broader digitalization agenda set by the national program "Digital Economy of the Russian Federation" in 2019.[5] The program aims for the integrated development of information infrastructure, personnel, digital technologies, information security, and creating legal and regulatory conditions for the development and implementation of relevant solutions in the economy, society, and public administration. A separate Ministry of Energy project "Digital Energy Industry" complements the above system of measures by increasing power supply reliability and creating a single industry-wide digital platform for real-time data transmission and the collection of reports.[6] The main constraints in Russia are due to excessive centralization, a focus on developing a unified energy system, an excessive number of intermediary organizations, and a high level of cross-subsidization which hampers making optimal decisions on the ground.

Japan, like Germany, has managed to achieve economic growth while reducing primary energy consumption (relative to the 1990 level). In 2018 the country's energy consumption was predominantly based on oil (about 40%), gas (21%), and coal (26%). RES and hydropower account for 10%. The share of nuclear generation decreased from 30% in 2011 to 3% in 2018 [IEA, 2020d] due to the Fukushima accident, which has caused a major disruption to the national power system. Combined with social factors (first of all the ageing of the population), this led to a gradual restructuring of the energy supply through the application of digital technologies. The socioeconomic development strategy Society 5.0 adopted in 2016[7] provides for analyzing various kinds of big data (on meteorology, power plants' operations, state of electric vehicles' batteries, households' energy consumption patterns) using AI. This will help firms to more accurately forecast and optimize energy consumption, redistributing the load on local sources, increasing energy savings, and reducing the impact on the environment and climate. According to the national Strategic Energy Plan, AI, IoT, virtual and augmented reality, and other advanced technologies will significantly impact the structure of energy consumption. The combined effect of digital solutions, energy storage systems, and renewable energy sources will contribute to achieving the climate-related goals of decarbonizing the economy. The risks associated with the energy transition in Japan include the growing political influence of China and India, increased technological competition, and cybersecurity threats [METI, 2018].

In Canada's primary energy consumption structure, oil and natural gas account for 30%, hydropower for 25%, coal and RES for 3-4%, and the rest comes from nuclear power plants. In generation hydropower prevails with an about 60% share. In terms of hydropower production, the country is behind only China and Brazil [EIA, 2019]. Combining clean energy with digital technologies is expected to reduce both the costs and emissions [The Generation Energy Council, 2018]. The industry digitalization priorities until 2050 include improving energy efficiency, managing demand and consumption, developing smart grids, expanding

[5] http://government.ru/rugovclassifier/614/events/, accessed on 24.02.2021.

[6] https://minenergo.gov.ru/node/14559, accessed on 19.02.2021.

[7] https://www8.cao.go.jp/cstp/english/society5_0/index.html, accessed on 10.02.2021.

electric vehicle infrastructure, and training personnel. Like other countries with a high level of digitalization and electrification, Canada faces the challenges of ensuring the industry's cybersecurity and sustainability [Canadian Electricity Association, 2019].

The European Digital Strategy which guides Germany, France, Spain, and other EU countries is based on the principles of openness, public participation, sustainable development, competition, and social justice [European Commission, 2021b]. The application of advanced information and communication technologies (ICT) including sensors, big data tools, AI, and IoT are expected to improve the connectivity, efficiency, reliability, and sustainability of energy systems [European Commission, 2021a] by harmonizing cooperation in the scope of the Energy Union[8] and the Digital Single Market.[9]

In Germany, oil (34% in 2018), natural gas (23%), and RES (14%) dominate the total consumption of primary resources. The country has set the most ambitious goals in the EU regarding the decarbonization of the economy, switching to clean energy sources, using smart meters, and other digital technologies [*Gangale et al.,* 2017]. The steps to achieve them are described in the Act on the Digitisation of the Energy Transition [BMWi, EY, 2019] and the Roadmap for Smart Energy Grids of the Future [BMWi, 2017]. This would require maintaining the system's reliability given the growing share of RES and the transition to active-adaptive networks, protecting personal data, and ensuring the compatibility of digital solutions [BMWi, 2017].

Brazil meets about 50% of its primary energy demand by burning oil and about 30% from RES and nuclear energy generation. Hydrogeneration covers up to 70% of the national electricity demand; up to 80% of electricity in the country is produced from RES. The Brazilian fuel and energy sector is undergoing major reforms which might change its landscape in the coming decades [WEF, Bain & Company, 2017]. The national digital transformation strategy E-Digital approved in 2018 [Government of Brazil, 2018] provides for developing smart cities through the application of IoT technologies, especially in areas such as mobility, utility companies' security, and smart energy and water grids. Smart meters, remote control and automated generation systems [WEF, Bain & Company, 2017], real-time simulators, other forecasting and monitoring technologies, and solutions designed to respond to changes are increasingly applied [RRE, 2017]. Digitalization will facilitate the integration of new RES such as wind and sun into the grid and the development of decentralized energy systems. Particular attention is paid to protecting the core national infrastructure, information (repositories, servers, etc.), and conventional energy (electric power, water supply, oil and gas, etc.) from cyberthreats; this is a joint public-private effort.

In South Korea's energy balance oil and coal prevail, followed by natural gas and nuclear energy. The Renewable Energy 2030 Implementation Plan adopted in December 2017 envisages increasing the share of RES in the total electricity generation from 3% to 20% [*Hong et al.,* 2019; IEA, 2020e]. In addition to stepping up solar and wind generation, the 9th Basic Plan for Power Supply and Demand aims to increase the flexibility of energy production, storage, transmission, and consumption, and maintain a high level of security of the energy supply system. Digitalization is also in the focus of the Korea Energy Master Plan 2035 and the Green New Deal 2020 post-crisis recovery strategy. The intention is to move on to managing demand by introducing smart grids and smart meters and increase energy efficiency by upgrading the ICT infrastructure [MOTIE, 2014]. The bottlenecks are the high dependence on imported fossil fuel resources, the geographic isolation of the national power grid, and the large distance between the power generation centers (located in the south of the country) and the main consumption areas. The latter issue is also typical for other countries such as Germany.

Despite the differences in the structure and consumption of primary energy resources and the technological level of the industry, almost all of the above countries see digital technologies as a tool for increasing productivity, switching to clean energy, and decentralizing their energy systems.

National Models and Stages of Digital Transformation in the Electric Power Industry

The analyzed sources allow one to distinguish between three national models of energy system digitalization. The first is applied in countries with decentralized governance (the United States and Canada) whose regions (states, provinces) have sufficient autonomy to choose the core power generation type and make technological decisions on the basis of market pull. This model allows one to test various approaches and choose the most effective ones, taking into account regional specifics (resources, population density, climate, etc.). National industry associations play a coordinating role in harmonizing the regional systems and solutions. A similar approach applies to developed countries which have sufficient energy resources.

The second digitalization model is adopted by economies highly dependent on imported fossil fuels, such

[8] https://ec.europa.eu/energy/topics/energy-strategy/energy-union_en, accessed on 19.03.2021.

[9] https://ec.europa.eu/digital-single-market/en/shaping-digital-single-market, accessed on 16.02.2021.

as India, Korea, Japan, and Germany. There, the accelerated transition to RES is prompted not only by climatic and environmental concerns, but also by the need to increase energy independence. In such a situation digitalization helps improve power systems' stability and sustainability, facilitate energy transfer from generation centers to consumers, and radically increase energy efficiency (technology push).

The third, mixed, model is based both on market mechanisms and directive regulation, depending on the electric power industry segment or the application area of digital solutions. This is typical for Russia, China, and Brazil. Though the government sets digitalization paths, industry companies and regions retain certain freedom in choosing the ways to accomplish the established goals.

The proposed models can be supplemented with two main stages of industry digitalization. The first involves the introduction of smart devices (primarily smart meters) and the creation of smart infrastructure. We mean upgrading the existing power grids and equipment, increasing the efficiency of using tangible assets and companies' processes through the extensive adoption of smart electricity metering systems, and improving the legal framework.

The adoption of smart meters which began about ten years ago, has not yet been completed in some countries (e.g., Brazil) due to regulatory barriers and delays with the development of standards [European Commission, 2011]. US utility tariff policy hinders the implementation of large digitalization projects [DOE, 2015]. By 2018, the number of smart meters was approaching the 100 million mark [BCSE, 2020].

The development of standards and legislative support for their application take considerable time. Countries which have reached the targets for the introduction of relevant regulations move on to the next stage: installing smart and next-generation sensors. For example, another wave of modernization of these devices is expected in China, due to their relatively short (5-8 years) life cycle, which should create stable domestic demand at 55-60 million units a year [BMWi, 2020a]. In Canada, the share of smart electricity meters has already reached 82% [Natural Resources Canada, 2018]. In South Korea the first such devices were installed in 2009-2013 in the Jeju province as part of a pilot project which allowed for testing these devices and then selling them on foreign markets (in Peru and Cambodia) [IEA, 2020f].

The second stage affects the entire value chain and involves the transition to clean energy sources. It implies the systemic transformation of the electric power industry through the application of digital technologies and clean energy, the construction of distributed energy grids and smart mobility infrastructure (including for electric vehicles), smart energy systems for buildings, and an increased range of digital services. A lot of innovative solutions are applied at this stage, such as predictive analytics based on machine learning algorithms, the automation of mutual settlements using distributed ledger systems, digital energy trading platforms [*Cardenas et al.*, 2014], advanced energy management systems, and cross-cutting digital platforms [*Vaio et al.*, 2021; *Menzel, Teubner,* 2020]. Digitalization affects consumers, suppliers, and partners of transmission and distribution companies.

Modern smart grid infrastructure provides consumers with new services based on online tracking of their energy consumption and its structure and allows for the use of differentiated tariffs. A similar approach is being taken in France where Linky meters support the management of low-voltage grids and tariff differentiation, along with accurate monitoring and predictive diagnostics to manage peak loads [European Commission, 2020]. In Brazil, the "white hourly tariff" allows for tracking households' behavior and on the basis of the collected data encourage users to reduce energy consumption during the 18:00 to 22:00 peak period [*Dantas et al.*, 2018; *Dranka, Ferreira,* 2020]. Global installation of smart meters would require about two billion dollars in investments [*Dranka, Ferreira,* 2020].

At this stage various digital technologies are introduced along the entire value chain, based on platform solutions. An example is the project of the Chinese electric power corporation SGCC (e-IoT) to create an "Internet of Energy ecosystem" integrating digital platforms, a demand management system, and other tools to improve internal efficiency. In the interests of the consumer, it is planned to develop services for the integration of power distribution and retail systems, and new models of cloud trading in energy resources [Energy Iceberg, 2019].

At each digitalization stage government support measures are applied, which can be divided into three groups: financial, regulatory, and other (Tables 2-4).

Financial tools promote R&D and the application of new technologies. They include grants, subsidies, R&D tax incentives, technology commercialization funds, government procurement, subsidies for purchasing certain products, contests, funding for startups, and special rates and conditions for the use of smart devices.

For example, in Russia in the framework of the National Technology Initiative, the EnergyNet roadmap has been implemented since 2016, which provides grants for the implementation and commercialization of ideas. EnergyNet digital solutions are aimed at optimizing energy consumption. A competent energy policy and targeted competitive incentives will promote them on the domestic and global markets. It is predicted that by 2035 Russian companies' share on

Table 2. **Financial Support of Digital Transformation in the Electric Power Industry**

Area	Mechanism	Country
R&D	Energy technology commercialization funds*	US
	Energy technology development grants	Germany
	Tax incentives for R&D	India
	Grants for development and commercialization of the EnergyNet roadmap projects in the scope of the National Technology Initiative	Russia
	Establishing and supporting advanced technology development centers (AI, etc.)	US
	Public-private partnerships to establish energy industry centers of excellence (with the participation of academia and small and medium business) to conduct R&D in priority areas	France
Introduction of digital solutions	Grants for the upgrading transmission and distribution networks (Smart Grid Investment Grant program)*	US
	Grants (special cooperation agreements) to study the potential of next-generation smart grids (their compatibility with the existing infrastructure) and energy storage technologies (Smart Grid Demonstration Programme)*	US
	Subsidies to buy electric vehicles	China
	Government procurement of electric vehicles to upgrade the conventional vehicle fleet	India
	Industry orders for equipment and other products of the sector	Russia
	Grants for distributed energy resources integration, storage devices, and electric vehicle projects	Canada
	Contests to select companies — leaders in implementing ICT strategies, with prizes	Japan
	Start-up support	India
	Export development funds for the commercialization of companies' clean energy solutions	Canada
Application	Differentiated tariffs to regulate peak loads using smart meters, depending on the time of day or season*	France
	Special tariff for interregional (intermunicipal) associations – a reduced rate for transmission within the association, and a higher one for external transmission*	France
	Special conditions for the implementation of smart meters when using a certain type of tariff (White Hourly Tariff)*	Brazil

Note for Tables 2-4. Tools which can be applied at the first digitization stage are marked with *.

Sources: authors, based on [EC-MAP, 2018; Natural Resources Canada, 2018; BMWi, EY, 2019; European Commission, 2019a; IEA, 2019b; SGCC, 2019; BMWi, 2020b; European Commission, 2020; IEA, 2020c; KAS, 2020; METI, 2020; DOE, 2021].

global markets will reach 3%-12%,[10] while their annual revenues will amount to $40 billion.[11]

Regulatory tools include legal requirements for handling and using devices and data. They involve certification rules, data availability, uniform standards, and "regulatory sandboxes". For example, German, French, Japanese, and other legislations have requirements for the certification of smart devices [European Commission, 2019a].

The third group of tools comprises *other support measures* including recommendations on technology application, developing cybersecurity standards and digitalization indicators, promoting consumer involvement in the development of energy supply platforms, building open data infrastructures, setting up digital platforms for electricity trading, developing new business models, and launching pilot energy supply projects.

Table 3. **Regulatory Incentives for the Digitalization of the Electric Power Industry**

Mechanism	Country
Mandatory certification requirement for smart devices (meters and hubs)*	Germany, France, Japan
Regulatory sandboxes as part of demonstration projects to test new energy supply models	South Korea
Legal requirement to make available data on electricity transmission on retail market	US
Legal requirement to set up information systems for managing power grid safety	Germany
Legal right of distributor organizations to set up concession electric vehicle charging stations on their territory	Brazil
Granting access to various data on storage, network infrastructure, and meteorology at regulator's request, using API	France
Online national energy code compliance system for planning and construction of buildings	India
Unified data standard, including data format and protocol, for use by power grid enterprises (Green Button or Energy Services Provider Interface Standard)	Canada

[10] Including reliable and flexible distribution grids, smart distributed energy and consumer services, and related industry segments (utilities and communal services).

[11] https://www.nti2035.ru/markets/docs/DK_energynet.pdf, accessed on 12.02.2021.

Table 4. **Other Mechanisms Promoting the Transition to a Digital Energy Industry**

Area	Mechanism	Country
Standardization	Development of standardization strategy: roadmap for developing technical standards in the form of recommendations	Germany
	Development of cybersecurity standards, including requirement to report incidents compromising, actually or potentially, the system's reliability	US
	Developing guidelines on strengthening the security of the industrial internet of things	China
	Annual monitoring of digitization progress	Germany
Integrated and platform solutions	Creating open federated data infrastructure for the integration of centralized and decentralized infrastructures into a homogeneous environment (joint project GAIA-X)	Germany, France
	Online platforms offering connection to electricity and gas grids	Russia
	Blockchain platforms for trading in surplus electricity, marketplaces based on market operators' data	Japan, France
	New business and energy supply models (Mieterstrom)	France
Testing and scaling	Living laboratories: testing technologies with a high readiness level in real-life conditions (existing legal and physical infrastructure) without special regulatory exemptions (SINTEG program)	Germany
	Pilot and demonstration projects to launch platforms and mobile applications based on blockchain, microgrids, and cloud platforms	US, China, South Korea
	Demonstration programs to support projects aimed at building electric vehicle charging infrastructure	Canada
	Demonstration projects on household energy management systems, energy management in buildings, virtual power plants	Japan
	Identifying best practices for launching and subsequent scaling of pilot projects (Digital electric grids areas)	Russia

At the second digitalization stage, the toolset expands due to the large amount of innovations along the entire value chain. A new area of regulation is industry data management [*Avancini et al.,* 2019]. In recent years a number of initiatives received support from national regulators.

The Franco-German integrated project GAIA-X implemented by an international non-profit association aims to create open distributed infrastructure for integrating centralized and decentralized networks into a single environment and develop appropriate regulations and services. As a result, a unified format for storing data on the state of infrastructure facilities and other information will emerge.

Uniform standards will allow for bringing providers of cloud solutions, high-performance computing, edge computing systems, and other market participants together on a common platform, thus expanding the range of available services. The project creates conditions for developing new business models (Landlord-to-Tenant Electricity Act[12]), setting up processing centers, providing data aggregation, and other services [BMWi, 2020b].

Many countries are developing regulations for handling information in the energy sector. In the US there is a legal requirement to make available data on electricity transmission on the retail market [IEA, 2019b]. A similar requirement for open interfaces to access data on electricity consumption, network infrastructure, and meteorological conditions applies in France [Catapult Energy Systems, 2019].

Regardless of the model, integration into a single network requires strengthening the information security of both hardware and software. Cybersecurity standards applied in the US require suppliers to notify customers of incidents threatening the system's reliability [Federal Register, 2019]. A unified standard adopted in the US and Canada in 2011 known as Green Button (Energy Services Provider Interface, ESPI) includes a format and a data exchange protocol between electricity suppliers and consumers using special applications [Natural Resources Canada, 2018].

Over the course of green digitalization, significant resources are allocated to finance R&D at public research organizations and centers of excellence, often in the form of public-private partnerships. Various incentives are applied to encourage the public to acquire new technologies. In Germany a project is underway to install energy storage systems with solar panels connected to the grid. Individual generation systems can transfer no more than 50% of the energy produced to the grid. The incentives for companies and individuals include investment grants covering 30% of the battery costs and a low-interest loan for the remaining 70%. Support is provided to install new solar panels and upgrade existing solar power plants with a nominal capacity under 30 kW/peak and service life of at least five years [DIW Berlin, 2013].

[12] The law makes supplying electricity to tenants more profitable for both parties to the lease and for the system operators who receive a surcharge from landlords in the amount of 2.2 to 3.8 cents per kWh. The system encourages the use of RES, in particular rooftop solar panels or combined power and heat generation systems. Previously almost all energy generated this way was supplied directly to the grid and did not reach the tenants due to the complexity of the business model for selling electricity to users and the lack of incentives for system operators. The new business model is particularly popular in regions with high tariffs for grid electricity, such as Berlin or Hamburg.

Electromobility remains a priority development area for the industry in practically all countries. Electric vehicles' appeal is increased by subsidies provided for their purchase. In China in 2019 the relevant infrastructure comprised over 500,000 charging points, which is 50% more than a year earlier. China accounts for 50% of global electric vehicle sales [BMWi, 2020a]. Electric vehicles with the ability not only to charge from the grid, but also give electricity back in line with the vehicle-to-grid (V2G) principle have an advantage [*Clement-Nyns et al.,* 2011; *Bibak, Tekiner-Moğulkoç,* 2021].

The ELBE project (Hamburg, Germany) aims to install over 7,400 smart electric vehicle charging stations based on the distributed system principle. The program participants can expect compensation in the amount of 40%-60% of the equipment or network modernization costs until September 2022, provided that the new stations are compatible with the city operator (so the latter will be able to adjust electricity consumption, including during peak hours) [IRENA, 2019; IEA, 2019c].

"Regulatory sandboxes" provide an opportunity to test new technologies under a special legal regime. In the case of the electric power industry, this involves new models for energy services provision [IEA-ISGAN, 2019]. In contrast, living laboratories are designed to test technologies with a high readiness level in real-life conditions, including the existing legal frameworks [*Ahl et al.,* 2020]. SINTEG is an example of a living laboratory: a program for the testing and subsequent scaling of infrastructure projects for RES generation in five German regions.

For consumers, there are various electronic platforms which simplify connecting to electricity and gas grids (Russia)[13] [Russian Ministry of Energy, 2019b] or trading in surplus generated electricity, and marketplaces based on market operators' data (Japan, France) [SETIC, 2018].

To compare the productivity of national green digitalization models on the basis of the results of literature analysis, the following indicators were selected:

- average duration of power outages [*Adeyemi et al.,* 2020; *Ahmad et al.,* 2021; *Dileep,* 2020] as a reliability criterion for relevant services;
- average share of electricity losses [*Xiong et al.,* 2018; *Leiden et al.,* 2021] as an indicator measuring the state of power grid equipment (affects the rate of digital technologies' application);
- share of smart meters in the total number of meters [*Adeyemi et al.,* 2020; *Bertolini et al.,* 2020; *Havle et al.,* 2019];
- share of electric vehicles in the country's total vehicle fleet [*Plötz et al.,* 2017];
- share of filling stations with electric vehicle charging functionality [*Ahmad et al.,* 2021; *Hirst,* 2020].

These indicator values are presented in Table 5.

Green digitalization indicators in the ten countries selected for analysis vary significantly. The average duration of power outages ranges from 21 to 348 minutes. Japan has the best value, the worst — India and the US (317 and 348 minutes, respectively).

Electricity losses during transmission also indicate the varying efficiency of national grids. In India they amount to about a third of all electricity generated, in Brazil 16%, and in Russia 11%. The lowest values of this indicator are shown by Japan (4%) and Germany (4.5%). In countries with an economy in transition, leakages typically exceed 10%, while in developed countries they remain below 5%. The share of smart meters in their total number ranges from 1% in India to 98%–99% in some European countries and China.

The lowest disparity was observed in the share of electric vehicles, which does not exceed 3% of the total vehicle fleet. France and Germany hold the highest value of this parameter with 2.7% and 2.96%, respectively. However, both in absolute terms and the number of charging stations for this vehicle type, China is in the lead.

In terms of indicators presented in Table 5, Russia lags far behind the EU countries. The duration of power outages for individuals in the country is regulated by law[14] which limits such periods to 24 consecutive hours and 72 hours per year. Their actual duration in 2019 did not exceed two hours,[15] but the media frequently reported emergency power outages and their adverse consequences in the Krasnoyarsk,[16] Pskov,[17] and other regions. The standards for energy losses during transmission via power grids are approved by the Russian Ministry of Energy.[18] According to market participants, actual technological losses do not exceed 11% (see Table 5).

An analysis of national and sectoral strategies allowed the authors to identify the social, climatic, and value effects of green digitalization, along with those potentially emerging in related industries. Social effects include reduced costs of new technologies for prosum-

[13] https://digital.gov.ru/uploaded/files/tsifrovaya-energetika16x915.pdf, accessed on 09.02.2021.

[14] Power quality standards in general-purpose power supply systems in accordance with GOST 32144 — 2013; RF Government Resolutions No. 354 of 06.05.2011 and No. 442 of 04.05.2012.

[15] https://tass.ru/ekonomika/7898243, accessed on 19.02.2021.

[16] https://www.rbc.ru/rbcfreenews/5efec2ab9a79477bda91c7e8, accessed on 19.02.2021.

[17] https://www.gtrkpskov.ru/news-feed/vesti-pskov/15165-v-pskovskoj-oblasti-proisoshli-massovye-otklyucheniya-elektroenergii.html, accessed on 19.02.2021.

[18] According to the RF Government Regulation No. 861 of 27.12.2004.

Table 5. **Characteristics of National Green Digitalization Models**

Indicator	China	US	India	Russia	Japan	Canada	Germany	Brazil	South Korea	France	Spain
Average duration of power outages (min.)	—	348 (2018)	317 (2018)	120 (2019)	21	—	—	—	—	—	—
Average share of electricity losses (%)	5.9 (2019)	5	33	11 (2019)	4	9	4.46 (2018)	16	—	6.41 (2018)	8.93 (2018)
Share of smart meters in the total number of meters (%)	99 (2018)	57	1 (2019)	10 (2018)	67 (2018)	80 (2019)	15	—	—	22.2 (2018)	93.1 (2018)
Share of electric vehicles in the country's total vehicle fleet (%)	0.94 (2018)	1.9 (2019)	0.3 (2019)	0.014 (2020)	1 (2019)	0.14 (2019)	2.96	—	—	2.7	1.31
Number of filling stations with electric vehicle charging functionality (units)	808 00 (2019)	26 000 (2019)	250 (2019)	1612 (2019)	7900 (2019)	5000 (2019)	27 459 (2019)	—	—	24 950 (2019)	5209 (2019)

Sources: authors, based on [Krisher, 2020; Business Standard, 2019; Center on Global Energy Policy, 2019; EIA, 2020a, 2020b; Electric autonomy, 2020; Electrical India, 2018; IEA, 2020c; Energy Efficiency & Renewable Energy, 2019; Financial Express, 2019, 2020; Gasgoo, 2018; Rivard, 2019; d'Entremont, 2020; Naik, 2020; M2M Research Series, 2018; Nhede, 2020; Spencer-Jones, 2020; Statista, 2021a, 2021b, 2021c; TEPCO, 2015, World Bank, 2021] and Autostat data (https://www.autostat.ru/news/42999/, accessed on 19.02.2021).

ers, the introduction of flexible tariffs for consumers, reduced power outage periods, and the increased availability of electricity in remote and isolated areas. The main climate-related advantage appears to be reduced greenhouse emissions due to more economical and efficient use of energy resources and the transition to RES. The value component amounts to changing consumer behavior patterns and setting sustainable development as a national-level priority instead of economic growth at any cost. The effects in related industries are associated with the emergence of new mobility services and the introduction of new construction standards.

Conclusion

Unlike other segments of the fuel and energy sector, the electric power industry is at the forefront of the digital transformation - from the introduction of cloud IoT platforms and specialized applications to the optimization of the entire energy production and consumption chain. It can be argued that the industry came as close as possible to the image of the desired digital economy future, proving that it is actually achievable. Digitalization, decarbonization, and decentralization have become key development vectors for the energy industry in most countries. Digital technologies pave the way for new business models and promote the active use of RES.

Three country models and two main stages of digital transformation of the industry were identified, which differ depending on the degree of decision-making centralization, the level of energy imports, and the focus on market pull or technology push. An analysis of national-level strategic documents allowed the authors to determine the social, climatic, and value effects, and assess their impact on related sectors.

The social effects include reduced costs and increased availability of new energy technologies due to the industry development, competition, and government support. The application of digital technologies in the electric power industry contributes to a more efficient consumption of resources by industry players and consumers as well as the reliable and balanced distribution of energy resources. The analysis of big data on consumer behavior allows suppliers to offer flexible tariffs based on energy consumption patterns. Lower costs and lower resource intensity help companies reduce their expenditures and tariffs, while decentralized systems increase the availability of electricity in remote and isolated areas. Companies' efforts to improve economic and technological efficiency directly affect the reliability and security of the electricity supply for consumers. In addition to the above effects, the digitalization of the electric power industry contributes to the sustainable growth of the sector and the whole economy.

Though governments and businesses declare their commitment to reducing the anthropogenic impact upon the environment and climate, at the operational level these goals do not always match the digitalization objectives. The more efficient use of resources (e.g., reducing transmission losses), improved energy efficiency, and the transition to clean energy highlight the link between digitalization and green growth. However, these transformations will not be possible without a change in values, which largely depends on the informational and educational activities of the state.

The transition to sustainable development and digital technologies leads to changes in many industries, including cross-industry effects such as the emergence of new business models and mobility patterns, the introduction of green standards in construction, and the development of new segments in the ICT industry

This paper was prepared in the scope of a grant provided by the Ministry of Science and Higher Education of the Russian Federation (Grant Agreement No. 075-15-2020-928).

References

Adeyemi A., Yan M., Shahidehpour M., Botero C., Guerra A.V., Gurung N., Zhang L., Paaso A. (2020) Blockchain Technology Applications in Power Distribution Systems. *The Electricity Journal*, 33(8), 106817. https://doi.org/10.1016/j.tej.2020.106817

Afanasyev V.Y., Lyubimova N.G., Ukolov V.F., Shayakhmetov S.R. (2019) Digitalisation of Energy Manufacture: Infrastructure, Supply Chain Strategy and Communication. *International Journal of Supply Chain Management*, 8(4), 601–609.

Afanasyev V.Ya., Ukolov V.F., Bolshakova O.I., Kislenko N.A., Alekseev A.O. (2020) Adaptive Impact Factor Research Concerning Effectiveness of the Introduction and Use of Digital Twins for Oil and Gas Deposits. *International Journal of Criminology and Sociology*, 9, 2043–2047. DOI:10.6000/1929-4409.2020.09.239

Ahl A., Yarime M., Goto M., Chopra S.S., Kumar N.M., Tanaka K., Sagawa D. (2020) Exploring Blockchain for the Energy Transition: Opportunities and Challenges Based on a Case Study in Japan. *Renewable and Sustainable Energy Reviews*, 117, 109488. https://doi.org/10.1016/j.rser.2019.109488

Ahmad T., Zhang D., Huang C., Zhang H., Dai N., Song Y., Chen H. (2021) Artificial Intelligence in Sustainable Energy Industry: Status Quo, Challenges and Opportunities. *Journal of Cleaner Production*, 289, 125834. https://doi.org/10.1016/j.jclepro.2021.125834

Anderson K., El Gamal A. (2017) Co-Optimising the Value of Storage in Energy and Regulation Service Markets. *Energy Systems*, 8(2), pp. 369–387. https://doi.org/10.1007/s12667-016-0201-0

Andoni M., Robu V., Flynn D., Abram S., Geach D., Jenkins D., Peacock A. (2019) Blockchain Technology in the Energy Sector: A Systematic Review of Challenges and Opportunities. *Renewable and Sustainable Energy Reviews*, 100, 143–174. https://doi.org/10.1016/j.rser.2018.10.014

Avancini D.B., Rodrigues J.J., Martins S.G., Rabêlo R.A., Al-Muhtadi J., Solic P. (2019) Energy Meters Evolution in Smart Grids: A Review. *Journal of Cleaner Production*, 217, 702–715. https://doi.org/10.1016/j.jclepro.2019.01.229

Bagdadee A.H., Hoque M.Z., Zhang L. (2020) IoT Based Wireless Sensor Network for Power Quality Control in Smart Grid. *Procedia Computer Science*, 167, 1148–1160. https://doi.org/10.1016/j.procs.2020.03.417

Barbier E.B. (2020) Greening the Post-Pandemic Recovery in the G20. *Environmental and Resource Economics*, 76(4), 685–703. https://doi.org/10.1007/s10640-020-00437-w

Batra P. (2019) *Geo Smart Energy — Building a National Integrated Management System*. https://geosmartindia.net/speaker/presentions2019/geosmart%20energy%20building%20national%20integrated%20management%20system%20Pankaj%20Batra.pdf, accessed 19.02.2021.

BCSE (2020) *Sustainable Energy in America*. https://www.bcse.org/wp-content/uploads/2020-Sustainable-Energy-in-America-Factbook.pdf#page=121, accessed on 19.02.2021.

BDEW (2019) *BDEW Energy Market Germany 2019 in German and English*. https://www.bdew.de/media/documents/Pub_20190603_Energy-Market-Germany-2019.pdf, accessed on 19.02.2021.

Beier G., Niehoff S., Ziems T., Xue B. (2017) Sustainability Aspects of a Digitalised Industry — A Comparative Study From China and Germany. *International Journal of Precision Engineering and Manufacturing-Green Technology*, 4(2), pp. 227–234. https://doi.org/10.1007/s40684-017-0028-8

Bertolini B., Buso M., Greco L. (2020) Competition in Smart Distribution Grids. *Energy Policy*, 145, 111729. https://doi.org/10.1016/j.enpol.2020.111729

Bibak B., Tekiner-Moğulkoç H. (2021) A Comprehensive Analysis of Vehicle to Grid (V2G) Systems and Scholarly Literature on the Application of Such Systems. *Renewable Energy Focus*, 36, 1–20. https://doi.org/10.1016/j.ref.2020.10.001

BMWi (2017) *Electricity 2030 — Concluding Paper*. https://www.bmwi.de/Redaktion/EN/Publikationen/electricity-2030-concluding-paper.html, accessed on 03.02.2021.

BMWi (2020a) *China Energy Transition Status Report 2020. Sino-German Energy Transition Project*. https://www.energypartnership.cn/fileadmin/user_upload/china/media_elements/publications/China_Energy_Transition_Status_Report.pdf, accessed on 03.02.2021.

BMWi (2020b) *GAIA-X: Driver of Digital Innovation in Europe. Featuring the Next Generation of Data Infrastructure*. https://www.bmwi.de/Redaktion/EN/Publikationen/gaia-x-driver-of-digital-innovation-in-europe.pdf?__blob=publicationFile&v=8, accessed on 03.02.2021.

BMWi, EY (2019) *Barometer Digitalisierung der Energiewende Wichtige Voraussetzungen für die Digitalisierung wurden geschaffen Berichtsjahr 2019*. https://www.bmwi.de/Redaktion/DE/Publikationen/Studien/barometer-digitalisierung-der-energiewende-berichtsjahr-2019.pdf?__blob=publicationFile&v=8, accessed on 15.02.2021.

Brown N., Brown I. (2019) *From Digital Business Strategy to Digital Transformation — How? A Systematic Literature Review*. Paper presented at the SAICSIT 2019 Conference, September 2019. https://doi.org/10.1145/3351108.3351122

Business Standard (2019) *Nearly 400,000 Electric Vehicles in India, UP Leads Race*. https://www.business-standard.com/article/automobile/nearly-400-000-electric-vehicles-in-india-up-leads-race-delhi-at-2nd-spot-119071500233_1.html, accessed on 19.02.2021.

Canadian Electricity Association (2019) *State of the Canadian Electricity Industry*. https://cea-ksiu6qbsd.netdna-ssl.com/wp-content/uploads/2019/02/AIO_Report_2019_Digital.pdf, accessed on 10.03.2021.

Cardenas J., Gemoets L., Ablanedo Rosas J., Sarfi R. (2014) A Literature Survey on Smart Grid Distribution: An Analytical Approach. *Journal of Cleaner Production*, 65, 202–216. https://doi.org/10.1016/j.jclepro.2013.09.019

Carvalho P. (2015) Smart Metering Deployment in Brazil. *Energy Procedia*, 83, 360–369. https://doi.org/10.1016/j.egypro.2015.12.211

Catapult Energy Systems (2019) *A Strategy for a Modern Digitalised Energy System*. https://es.catapult.org.uk/wp-content/uploads/2019/06/Catapult-Energy-Data-Taskforce-Report-A4-v4AW-Digital.pdf, accessed on 03.02.2021.

Cavanagh R. (2021) Energy Efficiency and Decarbonisation: Priorities for Regulated Utilities. *The Electricity Journal*, 34(2), 106908. https://doi.org/10.1016/j.tej.2020.106908

Center on Global Energy Policy (2019) *Electric Vehicle Charging In China And The United States*. https://energypolicy.columbia.edu/sites/default/files/file-uploads/EV_ChargingChina-CGEP_Report_Final.pdf, accessed on 19.02.2021.

Clement-Nyns K., Haesen E., Driesen J. (2011) The Impact of Vehicle-to-Grid on the Distribution Grid. *Electric Power Systems Research*, 81(1), 185–192. https://doi.org/10.1016/j.epsr.2010.08.007

D'Entremont C. (2020) *Why 80 Per Cent of Canadians are Already Using Smart Meters*. https://huddle.today/why-80-per-cent-of-canadians-are-already-using-smart-meters/, accessed on 13.02.2021.

Dantas G.D.A., de Castro N.J., Dias L., Antunes C.H., Vardiero P., Brandão R., Zamboni L. (2018) Public Policies for Smart Grids in Brazil. *Renewable and Sustainable Energy Reviews*, 92, pp. 501–512. https://doi.org/10.1016/j.rser.2018.04.077

Dellermann D., Fliaster A., Kolloch M. (2017) Innovation Risk in Digital Business Models: The German Energy Sector. *Journal of Business Strategy*, 38(5), 35–43. https://doi.org/10.1108/JBS-07-2016-0078

Di Vaio A., Palladino R., Pezzi A., Kalisz D.E. (2021) The Role of Digital Innovation in Knowledge Management Systems: A Systematic Literature Review. *Journal of Business Research*, 123, pp. 220–231. https://doi.org/10.1016/j.jbusres.2020.09.042

Dileep G. (2020) A Survey on Smart Grid Technologies and Applications. *Renewable Energy*, 146, pp. 2589–2625. https://doi.org/10.1016/j.renene.2019.08.092

DIW Berlin (2013) *Policy Efforts for the Development of Storage Technologies in the U.S. and Germany*. https://d-nb.info/1153062666/34, accessed on 19.02.2021.

DOE (2015) *United States Electricity Industry Primer,* Washington, D.C.: Department of Energy. https://www.energy.gov/sites/prod/files/2015/12/f28/united-states-electricity-industry-primer.pdf, accessed on 09.02.2021.

DOE (2021) *Recovery Act: Smart Grid Investment Grant Programme*, Washington, D.C.: Department of Energy. https://www.smartgrid.gov/recovery_act/overview/smart_grid_investment_grant_programme.html, accessed on 27.02.2021.

Dranka G.G., Ferreira P. (2020) Towards a Smart Grid Power System in Brazil: Challenges and Opportunities. *Energy Policy*, 136, 111033. https://doi.org/10.1016/j.enpol.2019.111033

EC-MAP (2018) *New Policy For An Era Of Energy Digitalisation: Power*. http://ec-map.org/wp-content/uploads/2018/10/Power-Whitepaper.pdf, accessed on 27.02.2021.

Edelstein P., Kilian L. (2007) *The Response of Business Fixed Investment to Changes in Energy Prices: A Test of Some Hypotheses About the Transmission of Energy Price Shocks*. https://repec.cepr.org/repec/cpr/ceprdp/DP6507.pdf, accessed on 19.02.2021.

EIA (2019) *Canada. Country analysis. Overview,* Washington, D.C.: Energy Information Administration. https://www.eia.gov/international/analysis/country/CAN, accessed on 09.03.2021.

EIA (2020a) *How Much Electricity Is Lost in Electricity Transmission and Distribution in the United States?*, Washington, D.C.: Energy Information Administration. https://www.eia.gov/tools/faqs/faq.php?id=105&t=3#:~:text=The%20U.S.%20Energy%20Information%20Administration,in%20the%20State%20Electricity%20Profiles, accessed on 10.02.2021.

EIA (2020b) *U.S. Customers Experienced an Average of Nearly Six Hours of Power Interruptions in 2018*, Washington, D.C.: Energy Information Administration. https://www.eia.gov/todayinenergy/detail.php?id=43915#:~:text=In%202018%2C%20power%20outage%20durations,averaged%205.8%20hours%20per%20customer, accessed on 10.02.2021.

Electric Autonomy (2020) *Canada's EV Charging Networks Are Growing at Pace, But More Is Needed*. https://electricautonomy.ca/2020/03/02/canadas-ev-charging-networks-2020/#/analyze?country=CA&fuel=ELEC&ev_levels=all&show_map=true, accessed on 10.02.2021.

Electrical India (2018) *Transmission Losses in India.* https://www.electricalindia.in/transmission-losses-in-india/, accessed on 13.02.2021.

Enerdata (2020) *Global Energy Statistical Yearbook 2020.* https://yearbook.enerdata.net/electricity/world-electricity-production-statistics.html, accessed on 19.02.2021.

Energy Efficiency & Renewable Energy (2019) *Plug-in Vehicle Sales Accounted for About 2% of All Light-Duty Vehicle Sales in the United States in 2019.* https://www.energy.gov/eere/vehicles/articles/fotw-1136-june-1-2020-plug-vehicle-sales-accounted-about-2-all-light-duty, accessed on 10.02.2021.

Energy Iceberg (2019) *Chinese Grids' Transformation to Benefit Digital & Tech Companies Globally*. https://energyiceberg.com/chinese-grids-transformation-to-benefit-digital-tech-companies-globally/, accessed on 19.02.2021.

Epiphaniou G., Bottarelli M., Al-Khateeb H., Ersotelos N.T., Kanyaru J., Nahar V. (2020) Smart Distributed Ledger Technologies in Industry 4.0: Challenges and Opportunities in Supply Chain Management. In: *Cyber Defence in the Age of AI, Smart Societies and Augmented Humanity* (eds. H. Jahankhani, S. Kendzierskyj, N. Chelvachandran, J. Ibarra Jimenez), Heidelberg, Dordrecht, London, New York: Springer, pp. 319–345. https://doi.org/10.1007/978-3-030-35746-7_15

European Commission (2011) *Smart Grids: From Innovation to Deployment,* Brussels: European Commission. https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52011SC0463&from=EN, accessed on 19.02.2021.

European Commission (2017) *Cyber Security in the Energy Sector. Recommendations for the European Commission on a European Strategic Framework and Potential Future Legislative Acts for the Energy Sector,* Brussels: European Commission. https://ec.europa.eu/energy/sites/ener/files/documents/eecsp_ _final.pdf, accessed on 09.02.2021.

European Commission (2019a) *Assessment and roadmap for the digital transformation of the energy sector towards an innovative internal energy market*, Brussels: European Commission. https://www.euneighbours.eu/sites/default/files/publications/2020-03/MJ0220185ENN.en_.pdf, accessed on 09.02.2021.

European Commission (2019b) *Digital Transformation in Transport, Construction, Energy, Government and Public Administration,* Brussels: European Commission. https://publications.jrc.ec.europa.eu/repository/bitstream/JRC116179/jrc_digital_transformation_final_on_line_en_baja_resoluci%c3%b3n_online.pdf, accessed on 09.02.2021.

European Commission (2020) *Integrated National Energy and Climate Plan for France,* Brussels: European Commission. https://ec.europa.eu/energy/sites/ener/files/documents/fr_final_necp_main_en.pdf, accessed on 19.02.2021.

European Commission (2021a) *Digitalisation,* Brussels: European Commission. https://ec.europa.eu/energy/topics/technology-and-innovation/digitalisation_en , accessed on 09.02.2021.

European Commission (2021b) *The European Digital Strategy,* Brussels: European Commission. https://ec.europa.eu/digital-single-market/en/content/european-digital-strategy, accessed on 09.02.2021.

Federal Register (2019) *Critical Infrastructure Protection Reliability Standard CIP-012-1-Cyber Security-Communications Between Control Centers*. https://www.federalregister.gov/documents/2019/04/24/2019-08236/critical-infrastructure-protection-reliability-standard-cip-012-1-cyber-security-communications, accessed on 09.02.2021.

Financial Express (2019) *Powered up: Average electricity cut duration falls in May*. https://www.financialexpress.com/economy/power-up-all-india-average-electricity-cut-duration-falls-in-may/1608184/, accessed on 10.02.2021.

Financial Express (2020) *Smart meters: Time to make that smart switch*. https://www.financialexpress.com/industry/smart-meters-time-to-make-that-smart-switch/2092936/, accessed on 13.02.2021.

Gangale F., Vasiljevska, J., Covrig, C., F., Mengolini, A., Fulli, G. (2017) *Smart grid projects outlook 2017*, Brussels: European Commission. https://publications.jrc.ec.europa.eu/repository/bitstream/JRC106796/sgp_outlook_2017-online.pdf, accessed on 09.02.2021.

Gasgoo (2018) *China car population reaches 235 million units, Ministry of Public Security*. http://autonews.gasgoo.com/china_news/70015270.html, accessed on 13.02.2021.

Gatto A., Drago C. (2020) Measuring and modeling energy resilience. *Ecological Economics*, 172. 106527. https://doi.org/10.1016/j.ecolecon.2019.106527

Ghobakhloo M. (2018) The future of manufacturing industry: A strategic roadmap toward Industry 4.0. *Journal of Manufacturing Technology Management*, 29(6), 910–936. https://doi.org/10.1108/JMTM-02-2018-0057

Government of Brazil (2018) *Brazilian Digital Transformation Strategy E-Digital.* https://www.gov.br/mcti/pt-br/centrais-de-conteudo/comunicados-mcti/estrategia-digital-brasileira/digitalstrategy.pdf, accessed on 09.02.2021.

Graf P., Jacobsen H. (2021) Institutional work in the transformation of the German energy sector. *Utilities Policy*, 68, 101107. https://doi.org/10.1016/j.jup.2020.101107

Havle B., Dursun M. (2019) *Digital Transformation in Energy Industry: A Literature Review for Future Studies*. Paper presented at the 3rd International Conference on Data Science and Business Analytics (ICDSBA) 11-12 October 2019. DOI: 10.1109/ICDSBA48748.2019.00043

Hirst D. (2020) *Electric vehicles and infrastructure* (Briefing Paper CBP07480). https://commonslibrary.parliament.uk/research-briefings/cbp-7480/, accessed on 06.07.2021.

Hong J., Kim J., Son W., Shin H., Kim N., Lee W.K., Kim J. (2019) Long-term energy strategy scenarios for South Korea: Transition to a sustainable energy system. *Energy Policy,* 127, 425–437. https://doi.org/10.1016/j.enpol.2018.11.055

IEA (2017) *Digitalisation and Energy,* Paris: International Energy Agency. https://iea.blob.core.windows.net/assets/b1e6600c-4e40-4d9c-809d-1d1724c763d5/DigitalisationandEnergy3.pdf, accessed on 09.02.2021.

IEA (2019a) *China Power System Transformation,* Paris: International Energy Agency. https://iea.blob.core.windows.net/assets/fd886bb9-27d8-4d5d-a03f-38cb34b77ed7/China_Power_System_Transformation.pdf, accessed on 09.02.2021.

IEA (2019b) *Energy Policy of the IEA countries. The United States 2019 Review,* Paris: International Energy Agency. https://webstore.iea.org/download/summary/2829, accessed on 09.02.2021.

IEA (2019c) *Project ELBE (incentive programmeme for EV charging infrastructure),* Paris: International Energy Agency. https://www.iea.org/policies/8540-project-elbe-incentive-programmeme-for-ev-charging-infrastructure, accessed on 09.02.2021.

IEA (2020a) *Electricity Market Report – December 2020,* Paris: International Energy Agency. https://iea.blob.core.windows.net/assets/a695ae98-cec1-43ce-9cab-c37bb0143a05/Electricity_Market_Report_December_2020.pdf, accessed on 09.02.2021.

IEA (2020b) *Energy end-use data collection methodologies and the emerging role of digital technologies,* Paris: International Energy Agency. https://iea.blob.core.windows.net/assets/34e2659e-809c-4299-bb51-c0343257af08/Energy_end-use_data_collection_methodologies_and_the_emerging_role_of_digital_technologies.pdf, accessed on 15.02.2021.

IEA (2020c) *India 2020. Energy Policy Review,* Paris: International Energy Agency. https://niti.gov.in/sites/default/files/2020-01/IEA-India%202020-In-depth-EnergyPolicy_0.pdf, accessed on 07.02.2021.

IEA (2020d) *Japan,* Paris: International Energy Agency. https://www.iea.org/countries/japan, accessed on 09.02.2021.

IEA (2020e) *Korea,* Paris: International Energy Agency. https://www.iea.org/countries/korea, accessed on 09.02.2021.

IEA (2020f) *World Energy Outlook 2020,* Paris: International Energy Agency. https://www.iea.org/reports/world-energy-outlook-2020, accessed on 09.02.2021.

IEA-ISGAN (2019) *Innovative Regulatory Approaches with Focus on Experimental Sandboxes,* Paris: International Energy Agency. https://www.iea-isgan.org/wp-content/uploads/2019/05/ISGAN_Casebook-on-Regulatory-Sandbox-A2-1.pdf, accessed on 19.02.2021.

IRENA (2019) *Electrification with renewables: Driving the transformation of energy services,* Abu-Dhabi: IRENA. https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2019/Jan/IRENA_RE-Electrification_SGCC_2019_preview.pdf, accessed on 09.02.2021.

IRENA (2020) *Renewable capacity statistics 2020,* Abu-Dhabi: IRENA. https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2020/Mar/IRENA_RE_Capacity_Statistics_2020.pdf, accessed on 09.02.2021.

Kamble S.S., Gunasekaran A., Gawankar S.A. (2018) Sustainable Industry 4.0 framework: A systematic literature review identifying the current trends and future perspectives. *Process Safety and Environmental Protection*, 117, 408–425. https://doi.org/10.1016/j.psep.2018.05.009

Kang H.S., Lee J.Y., Choi S., Kim H., Park J.H., Son J.Y., Do Noh S. (2016) Smart manufacturing: Past research, present findings, and future directions. *International Journal of Precision Engineering and Manufacturing-Green Technology*, 3(1), 111–128. https://doi.org/10.1007/s40684-016-0015-5

KAS (2020) *Sustainable Energy and Digitalisation: Practices and Perspectives in Asia-Pacific*. https://www.kas.de/documents/265079/265128/Sustainable+Energy+and+Digitalisation+Practices+and+Perspectives+in+Asia+Pacific.pdf/a1a26d16-fa77-ac3f-c688-92d91bca6834?version=1.0&t=1581407991474, accessed on 19.02.2021.

Ketter W., Collins J., Saar-Tsechansky M., Marom O. (2018) Information systems for a smart electricity grid: Emerging challenges and opportunities. *ACM Transactions on Management Information Systems (TMIS)*, 9(3), 1–22. https://doi.org/10.1145/3230712

Korachi Z., Bounabat B. (2019) *Towards a Maturity Model for Digital Strategy Assessment*. In: *Proceedings of the AI2SD 2019 Conference,* Heidelberg, Dordrecht, London, New York: Springer, pp. 456–470. DOI: 10.1007/978-3-030-36674-2_47

Krisher T. (2020) *Plug it in: Electric car charging station numbers are rising*. https://apnews.com/article/business-u-s-news-technology-detroit-electric-vehicles-0dbe44f4626fcfd6b3ccee274980188e#:~:text=There%20are%20now%2026%2C000%20electric,with%20more%20than%2084%2C000%20plugs, accessed on 13.02.2021.

Leiden A., Herrmann C., Thiede S. (2021) Cyber-physical production system approach for energy and resource efficient planning and operation of plating process chains. *Journal of Cleaner Production*, 280, 125160. https://doi.org/10.1016/j.jclepro.2020.125160

Lichtenthaler U. (2020) Building blocks of successful digital transformation: Complementing technology and market issues. *International Journal of Innovation and Technology Management*, 17(1), 1–14. https://doi.org/10.1142/S0219877020500042

M2M Research Series (2018) *Smart Metering in North America and Asia-Pacific*. https://www.marketresearch.com/Berg-Insight-v2702/Smart-Metering-North-America-Asia-12517854/, accessed on 10.02.2021.

Malerba F. (2002) Sectoral systems of innovation and production. *Research Policy*, 31(2), 247–264. https://doi.org/10.1016/S0048-7333(01)00139-1

McKinsey & Company (2019) *Unlocking the value of digital operations in electric-power generation*. https://www.mckinsey.com/industries/electric-power-and-natural-gas/our-insights/unlocking-the-value-of-digital-operations-in-electric-power-generation#, accessed on 19.02.2021.

Menzel T., Teubner T. (2020) Green energy platform economics – understanding platformisation and sustainabilisation in the energy sector. *International Journal of Energy Sector Management*, 15(3), 456–475. https://doi.org/10.1108/IJESM-05-2020-0022

METI (2018) *Strategic Energy Plan*. https://www.enecho.meti.go.jp/en/category/others/basic_plan/5th/pdf/strategic_energy_plan.pdf, accessed on 08.02.2021.

METI (2020) *Guidebook on Corporate Governance for Privacy in Digital Transformation (DX) ver.1.0 Formulated*. https://www.meti.go.jp/english/press/2020/0828_006.html, accessed on 08.02.2021.

Midttun A., Piccini P.B. (2017) Facing the climate and digital challenge: European energy industry from boom to crisis and transformation. *Energy Policy*, 108, 330–343. https://doi.org/10.1016/j.enpol.2017.05.046

Mika B., Goudz A. (2020) Blockchain-technology in the energy industry: Blockchain as a driver of the energy revolution? With focus on the situation in Germany. *Energy Systems*, 12, 285–355. https://doi.org/10.1007/s12667-020-00391-y

Montevecchi F., Stickler T., Hintemann R., Hinterholzer S. (2020) *Energy-efficient Cloud Computing Technologies and Policies for an Eco-friendly Cloud Market*, Brussels: European Commission. https://www.researchgate.net/profile/Simon_Hinterholzer/publication/345687292_Energy-efficient_Cloud_Computing_Technologies_and_Policies_for_an_Eco-friendly_Cloud_Market/links/5faacbcf4585150781066c41/Energy-efficient-Cloud-Computing-Technologies-and-Policies-for-an-Eco-friendly-Cloud-Market.pdf, accessed on 19.02.2021.

MOTIE (2014) *Korea Energy Master Plan. Outlook & Policies to 2035.* https://www.motie.go.kr/common/download.do?fid=bbs&bbs_cd_n=72&bbs_seq_n=209286&file_seq_n=2, accessed on 19.02.2021.

Müller J.M., Kiel D., Voigt K.I. (2018) What drives the implementation of Industry 4.0? The role of opportunities and challenges in the context of sustainability. *Sustainability*, 10(1), 247. https://doi.org/10.3390/su10010247

Naik A.R. (2020) *The Math Behind India's Electric Vehicle Charging Infrastructure.* https://inc42.com/features/the-math-behind-indias-electric-vehicle-charging-infrastructure/#:~:text=According%20to%20a%20MarketWatch%2C%20at,expected%20to%20witness%20massive%20growth, accessed on 113.02.2021.

Natural Resources Canada (2018) *Smart Grid in Canada.* https://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/canmetenergy/pdf/Smart%20Grid%20in%20Canada%20Report%20Web%20FINAL%20EN.pdf, accessed on 09.02.2021.

Newberry S. (2001) Network structures, consumers and accountability in New Zealand. In: *Learning from International Public Management Reform: Part A* (eds. L.R. Jones, J. Guthrie, P. Steane), Bingley: Emerald Group Publishing Limited, pp. 257–278. https://doi.org/10.1016/S0732-1317(01)11054-7

Noussan M., Raimondi P.P., Scita R., Hafner M. (2021) The Role of Green and Blue Hydrogen in the Energy Transition — A Technological and Geopolitical Perspective. *Sustainability*, 13(1), 298. https://doi.org/10.3390/su13010298

OECD (2019a) *Measuring the Digital Transformation: A Roadmap for the Future,* Paris: OECD. https://www.oecd.org/going-digital/measurement-roadmap.pdf, accessed on 09.02.2021.

OECD (2019b) *Vectors of Digital Transformation OECD Digital Economy Papers,* Paris: OECD. https://www.sipotra.it/wp-content/uploads/2019/03/VECTORS-OF-DIGITAL-TRANSFORMATION.pdf, accessed on 14.02.2021.

Plötz P., Sprei F., Gnann T. (2017) *What are the effects of incentives on plugin electric vehicle sales in Europe?* Paper presented at the ECEEE 2017 Summer Study – Consumption, Efficiency & Limits. https://www.researchgate.net/publication/318209508_What_are_the_effects_of_incentives_on_plug-in_electric_vehicle_sales_in_Europe, accessed on 09.02.2021.

Ratnam K.S., Palanisamy K., Yang G. (2020) Future low-inertia power systems: Requirements, issues, and solutions. A review. *Renewable and Sustainable Energy Reviews*, 124, 109773. https://doi.org/10.1016/j.rser.2020.109773

Rivard G. (2019) *Over 40,000 Plug-In Cars Sold in Canada.* https://www.guideautoweb.com/en/articles/52849/over-40-000-plug-in-cars-sold-in-canada-so-far-in-2019/, accessed on 13.02.2021.

Rodríguez F., Sánchez-Guardamino I., Martín F., Fontán L. (2020) Non-intrusive, self-supplying and wireless sensor for monitoring grounding cable in smart grids. *Sensors and Actuators A: Physical,* 316, 112417. https://doi.org/10.1016/j.sna.2020.112417

RRE (2017) *Digitalisation in the Brazilian Energy Sector: Time for Disruption?* https://digital.hbs.edu/platform-rctom/submission/digitalisation-in-the-brazilian-energy-sector-time-for-disruption/#, accessed on 19.02.2021.

Schwieters N., Hasse F., von Perfall A., Maas H., Willms A., Lenz F. (2016) *Deutschlands energieversorger werden digital*, Frankfurt: PricewaterhouseCoopers. https://www.pwc.de/de/pressemitteilungen/2016/deutschlands-energieversorger-werden-digital-aber-zu-langsam.html, accessed on 19.02.2021.

SETIC (2018) *Digitalisation of the Energy sector.* https://publications.jrc.ec.europa.eu/repository/bitstream/JRC113569/setis_magazine_17_online.pdf, accessed on 09.02.2021.

SGCC (2019) *Internet of Things White Paper.* http://www.sgcc.com.cn/html/files/2019-10/14/20191014235609307380194.pdf, accessed on 08.02.2021.

Shahidehpour M., Fotuhi-Friuzabad M. (2016) Grid modernisation for enhancing the resilience, reliability, economics, sustainability, and security of electricity grid in an uncertain environment. *Scientia Iranica*, 23(6), 2862–2873. DOI: 10.24200/SCI.2016.3995

Song E.Y., FitzPatrick G.J., Lee K.B. (2017) Smart sensors and standard-based interoperability in smart grids. *IEEE Sensors Journal,* 17(23), 7723–7730. DOI: 10.1109/JSEN.2017.2729893

Soshinskaya M., Crijns-Graus W.H.J., Guerrero J.M., Vasquez J.C. (2014) Microgrids: Experiences, barriers and success factors. *Renewable and Sustainable Energy Reviews,* 40, 659–672. https://doi.org/10.1016/j.rser.2014.07.198

Statista (2021a) *Electric car market share in Japan 2010-2019.* https://www.statista.com/statistics/711994/japan-electric-car-market-share/#:~:text=As%20of%202019%2C%20approximately%200.9,and%202018%20were%20expanding%20rapidly, accessed on 10.02.2021..

Statista (2021b) *Electric power transmission loss in China from 2010 to 2019.* https://www.statista.com/statistics/302292/china-electric-power-transmission-loss/#:~:text=Electric%20power%20transmission%20loss%20in%20China%20 2010%2D2019&text=This%20statistic%20represents%20electric%20power,to%20transmission%20and%20 distribution%20resistance, accessed on 13.02.2021.

Statista (2021c) *Number of EVSE fast chargers in Japan 2010-2019.* https://www.statista.com/statistics/712010/japan-evse-fast-charger-stock/, accessed on 10.02.2021.

Teece D.J. (2018) Profiting from innovation in the digital economy: Enabling technologies, standards, and licensing models in the wireless world. *Research Policy,* 47(8), 1367–1387. https://doi.org/10.1016/j.respol.2017.01.015

TEPCO (2015) *TEPCO Power Grid.* https://www.tepco.co.jp/en/pg/supply/quality/index-e.html

The Generation Energy Council (2018) *Canada's Energy Transition. Getting to our Energy Future, Together. Generation Energy Council Report.* https://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/energy/CoucilReport_june27_English_Web.pdf, accessed on 10.03.2021.

Tripathi V., Kaur A. (2020) Socially responsible investing: Performance evaluation of BRICS nations. *Journal of Advances in Management Research*, 17(4), 525–547. https://doi.org/10.1108/JAMR-02-2020-0020

Waite M., Cohen E., Torbey H., Piccirilli M., Tian Y., Modi V. (2017) Global trends in urban electricity demands for cooling and heating. *Energy,* 127, 786–802. https://doi.org/10.1016/j.energy.2017.03.095

WEF (2016) *Electricity: uncovering value through digital transformation,* Geneva: World Economic Forum. https://reports.weforum.org/digital-transformation/electricity-an-industry-ready-for-digitisation/, accessed on 09.02.2021.

WEF, Bain & Company (2017) *The Future of Electricity: New Technologies Transforming the Grid Edge*, Geneva: World Economic Forum. https://media.bain.com/Images/WEF_Future_of_Electricity_2017.pdf, accessed on 19.02.2021.

Wertani H., Salem J.B., Lakhoua M.N. (2020) Analysis and supervision of a smart grid system with a systemic tool. *The Electricity Journal,* 33(6), 106784. https://doi.org/10.1016/j.tej.2020.106784

World Bank (2021) *Electric power transmission and distribution losses (% of output).* https://data.worldbank.org/indicator/EG.ELC.LOSS.ZS, accessed on 19.02.2021.

Xiong R., Chen H., Wang C., Sun F. (2018) Towards a smarter hybrid energy storage system based on battery and ultracapacitor – A critical review on topology and energy management. *Journal of Cleaner Production*, 202, 1228e1240. https://doi.org/10.1016/j.jclepro.2018.08.134

Zaoui F., Souissi N. (2020) Roadmap for digital transformation: A literature review. *Procedia Computer Science*, 175, 621–628. https://doi.org/10.1016/j.procs.2020.07.090

Zhu Z., Li X., Ding Y., Liu Z. (2020) Demand response capacity constrained optimisation of multicast routing in smart grid. *International Journal of Wireless and Mobile Computing*, 19(1), 33–41. DOI: 10.1504/IJWMC.2020.109259

Transformation of Value in Innovative Business Models: The Case of Pharmaceutical Market

Denis Klimanov
Researcher, Laboratory of network organizational forms, klimanov_denis@inbox.ru

Olga Tretyak
Tenured Professor, Head of Laboratory of network organizational forms, otretyak@hse.ru

National Research University Higher School of Economics, 28/11 Shabolovka Str., Bldg 9, 119049 Moscow, Russia

Uri Goren
Associate Director Digital Customer Engagement, uri.goren@teva.co.il

Teva Pharmaceuticals, 5 Basel St. Petach Tikva 49131, Israel

Timothy White
Vice President and Head of Global Digital Commercial, timothy.white@tevaeu.com

Teva Pharmaceuticals, Piet Heinkade 107, 1019 GM Amsterdam, Netherlands

Abstract

Creating and developing innovative business models (BM) is currently one of the key success factors for contemporary business. Rapid changes in the world triggered by the COVID-19 crisis happening now reemphasize the need to better understand how BM can be successfully innovated on different markets. The digital component of BM innovation comes under a special spotlight as the NASDAQ stock index representing the aggregated value of technological companies reached its all-time high in June 2020. In this current paper, we review innovation strategies at the corporate level using the example of a company within the pharmaceutical industry through the prism of BM innovation. In particular, this study demonstrates how BM innovation can be developed and implemented in practice within the pharmaceutical market, which accelerates its digital transformation to increase the value it brings to healthcare systems around the world while sustaining the ongoing crisis. In order to do that, the current paper offers a framework for BM innovation that defines BM elements, BM innovation aspects, and BM innovation logic. This new approach is applied to undertake a deep analysis of opportunities to build innovative BM using the case of a pharmaceutical market. This paper uses the case study method to demonstrate BM innovation insights. The research described in this paper is of a cross-border nature and includes the analysis of a pharmaceutical company's BM on six markets representing different value creation systems and mechanisms (Russia, Ukraine, Thailand, Chile, Mexico, and Israel). This paper demonstrates how technological innovations can be activated using managerial tools and insights and also how they can be combined into the holistic system based on the needs of the key value chain actors.

Keywords: business model; innovation; transformation of value; corporate strategies; pharmaceutical market; case studies

Citation: Klimanov D., Tretyak O., Goren U., White T. (2021) Transformation of Value in Innovative Business Models: The Case of Pharmaceutical Market. *Foresight and STI Governance*, 15(3), 52–65. DOI: 10.17323/2500-2597.2021.3.52.65

Introduction

Contemporary business model (BM) research has been increasing its focus on BM innovation. Because BM primarily deals with the complex process of value creation and delivery to the end consumer, each time a question arises as to how businesses can better align with consumer needs, the aim is to satisfy them in the most effective way that will allow to the firm not only to satisfy the consumer, but also keep businesses commercially successful.

There are many factors that force businesses to substantially change their BM, such as: increasing competition, lowering entry barriers to the industry, strengthening government regulations, and, of course, the technological boom increasing its pace every day. Economic shocks recently experienced by the world in 2020 due to the novel coronavirus (COVID-19) pandemic reemphasize the need to innovate BM and rethink innovation opportunities. Digitization, which is happening across the value chain, is accelerating now due to the pandemic's impact. The process of digitization is changing the configuration of the value chain as well as companies' BM when entering and operating on various markets. Customer-centric BM and pragmatic orientation on changing customer needs becomes a cornerstone of BM innovation directions at most companies. While the value of many businesses has been severely hit by the novel crisis (especially those representing the so-called BEACH sector – booking, entertainment, airlines, cruises, and hotels[1] [*Neufeld,* 2020]), we are currently observing a sharp increase in stock prices of companies that are in the center of fighting with the consequences of the pandemic (especially IT companies). Tech companies rule value, with Microsoft, Apple, Amazon, Alphabet, Facebook, and Alibaba being among the top 10 companies in the world by market capitalization[2], which means that technology plays a very important role in the commercial success of many companies around the world. At the same time, the rapid adoption of technologies should be accompanied by effective managerial actions to stimulate competitive and sustainable BM innovation.

An industry, where the transformation of value due to BM innovation coupled with technological advancements is especially important, is the pharmaceutical sector. The value chain in this industry becomes more complex with the increasing impact of digitization, which creates the need to reevaluate managerial technologies used to create successful BMs. With increasing costs of promotion, increasing competition, and customers becoming more and more knowledgeable and demanding, there is a strong need to transform the value that is delivered by pharmaceutical manufacturers to the key actors in their business network, such as doctors, pharmacies, healthcare institutions, wholesalers, government, and, of course, end consumers. While pharmaceutical sales representatives' detailing was a key information source for both doctors and pharmacies in the past, currently they lose their position to internet, where key customers of pharmaceutical companies search for the needed information about drugs and therapeutic practices. At the same time, the access to doctors' offices becomes more restricted, due to strengthening government regulations and also due to the limited time that a doctor can dedicate to each patient.[3] Sales force still accounts for the biggest expense in pharmaceutical companies' advertising and promotion budget, while margins are significantly reduced. Due to these changes many companies have started actively investing in digital promotion activities that are less costly and in many cases better perceived by their customers. Due to the novel coronavirus pandemic, remote promotion and remote communication with customers becomes a key building block in the strategies of the majority of pharmaceutical businesses. Companies focus on helping doctors and patients deal with the current situation and get their therapies and treatments with minimum supply disruptions.

In the current paper, we review the innovation strategies along the value chain on the corporate level using the example of a company within the pharmaceutical industry through the prism of BM innovation. As suggested by multiple research studies [*Keen, Qureshi,* 2006; *Teece,* 2010], BM and strategy research are very much interconnected. For a long time, strategy served as an overarching term that links internal company resources with its external environment and helps to define and reach its objectives. The research suggests that BM defines the principles, which are used to build the company strategy, especially considering the boundaries of a BM, which go beyond the boundaries of a single company and include other actors, such as suppliers, distribution channels, and end consumers [*Klimanov, Tretyak,* 2014]. Thus, BM describes what value is created for the customer, how it is created, and how companies generate profits from this process. For this purpose, this paper develops a framework to study BM innovation processes and outcomes, based on existing research in this area. The proposed BM innovation framework is applied to improve a pharmaceutical company's BM using the examples of markets around the world that present different value creation systems, such as Russia, Thailand, Ukraine, Chile, Israel, and Mexico. The countries were selected following the geographical and organizational structure of a studied company as well as due to the fact that they have remarkable differences in terms of the market structure and key actors and help demonstrate how a company can harness managerial technologies to create value on different markets. This paper classifies BM on these markets into several archetypes, which are then aligned with specific value transformation mechanisms that are used to drive BM innovation and to create value on the pharmaceutical market. This paper also explores how the company reacts to existing challenges to better understand how to create managerial technologies that can be used to harness the advantages of increasing digitization.

Developing a Framework for BM Innovation

Most of the existing research on BM highlights value creation, value delivery to the customer, and value capture as key ele-

[1] https://www.visualcapitalist.com/covid-19-downturn-beach-stocks/, accessed 17.06.2021.

[2] https://ycharts.com/, accessed 08.07.2021.

[3] https://www.policymed.com/2014/07/sales-rep-access-to-doctors-at-all-time-low-accessible-prescribers-down-from-77-in-2008-to-51-in-201.html, accessed 17.06.2021.

ments of BM understanding [*Chesbrough, Rosenbloom,* 2002; *Teece,* 2010; *Yang et al.,* 2017; *Leischnig et al.,* 2017]. At the same time, many authors agree that a BM is not centered on a single firm and includes other actors of a value chain, such as suppliers, distribution channels, government authorities, and also end consumers, who basically define the commercial success of a BM [*Nenonen, Storbacka,* 2010; *Palo, Tahtinen,* 2013; *Velu,* 2016]. A firm's actions cannot be seen in isolation on a market and the action of one actor can directly affect the actions of others [*Hynes, Elwell,* 2016]. It is argued that network BM is a powerful tool for innovation, exploring access to competencies via partnerships with other firms [*Lindgren et al.,* 2010; *Klimanov, Tretyak,* 2014]. To further develop this direction of research we will build our framework based on a synthesized definition of a BM that consolidates the views of the most well-known scholars studying BM [*Klimanov, Tretyak,* 2019]: *BM represents a scheme of value chain actors' interaction that is performed to create and deliver value to the customer and also to capture profits from these joint activities.* This understanding of BM also leads to a different understanding of innovations within the BM.

There is a number of research perspectives that contribute to the theoretical foundations of BM innovation. The roots of BM innovation studies lie in economics theory [*Teece,* 2010], focused on transaction cost economics, and Shumpeterian innovation [*Amit, Zott,* 2012], which then evolved into different focus areas of management studies, such as innovation management [*Chesbrough, Rosenbloom,* 2002; *Chesbrough,* 2007; *Foss, Saebi,* 2016], business strategy and strategic entrepreneurship [*Schneider, Spieth,* 2013], organizational networks theory [*Palo, Tahtinen,* 2013; *Hynes, Elwell,* 2016], resource-based view [*Velu,* 2016], dynamic capabilities [*Schneider, Spieth,* 2013], sustainability innovation, stakeholder theory, product-service systems [*Evans et al.,* 2017], and others.

While BMs have interconnections with many disciplines, some of the most obvious and holistic similarities can be found in marketing studies, and we will focus further specifically on marketing aspects of BM innovation. In general, marketing plays a crucial role in the contemporary understanding of BM as the essence of BM is strongly aligned with many key principles of this discipline [*Leischnig et al.,* 2017; *Robertson,* 2017; *Ehret et al.,* 2013; *Gatignon et al.,* 2017]. The key connections between marketing and BM research are described in [*Klimanov, Tretyak,* 2019]: value-related activities and themes (such as value proposition, value capturing/appropriation, value offering/delivery, value drivers, value creation, and value communication), value chains and networks, and other core marketing activities focused on the customer (such as customer segmentation, customer relationships, pricing and branding, and others). Therefore, marketing innovation can be studied as an essential area of BM innovation by analyzing how new approaches to promotion can affect the value creation process as well as commercial success of a BM. In the current paper, we demonstrate how marketing innovation coupled with technological advancements is developed and executed using managerial capabilities to transform and innovate the pharmaceutical company's BM on different markets in order to fit the needs of the key pharmaceutical market actors.

Based on the lessons from the literature on BM innovation, and also capitalizing on innovation management and stakeholder theory, we developed a framework to model and demonstrate the structure and process of BM innovation (Figure 1). This framework is further used to illustrate the BM transformation case study. The basis of the framework is formed by the modification of the value chain and innovations within it, which defines the BM innovation opportunities. BM innovations are reviewed in the context of a company strategy, which in turn depends not only upon the company itself, but on the whole value chain that it develops.

This framework conceptualizes a BM as a network of actors jointly creating and delivering value to the end consumer and it acknowledges the assumptions highlighted by many previous studies. There are three key dimensions: BM elements/layers, BM innovation aspects, and BM innovation logic. The assumptions of the framework are aligned with several previous concepts decomposing BM into stages linking the innovation process and innovation outcomes [*Foss, Saebi,* 2016; Schneider, Spieth, 2013], but with a broader perspective on how the innovation process can be linked with the network nature of a BM and how it can be further applied in business practice. The framework builds on the conceptual BM presented earlier in [*Klimanov, Tretyak,* 2014].

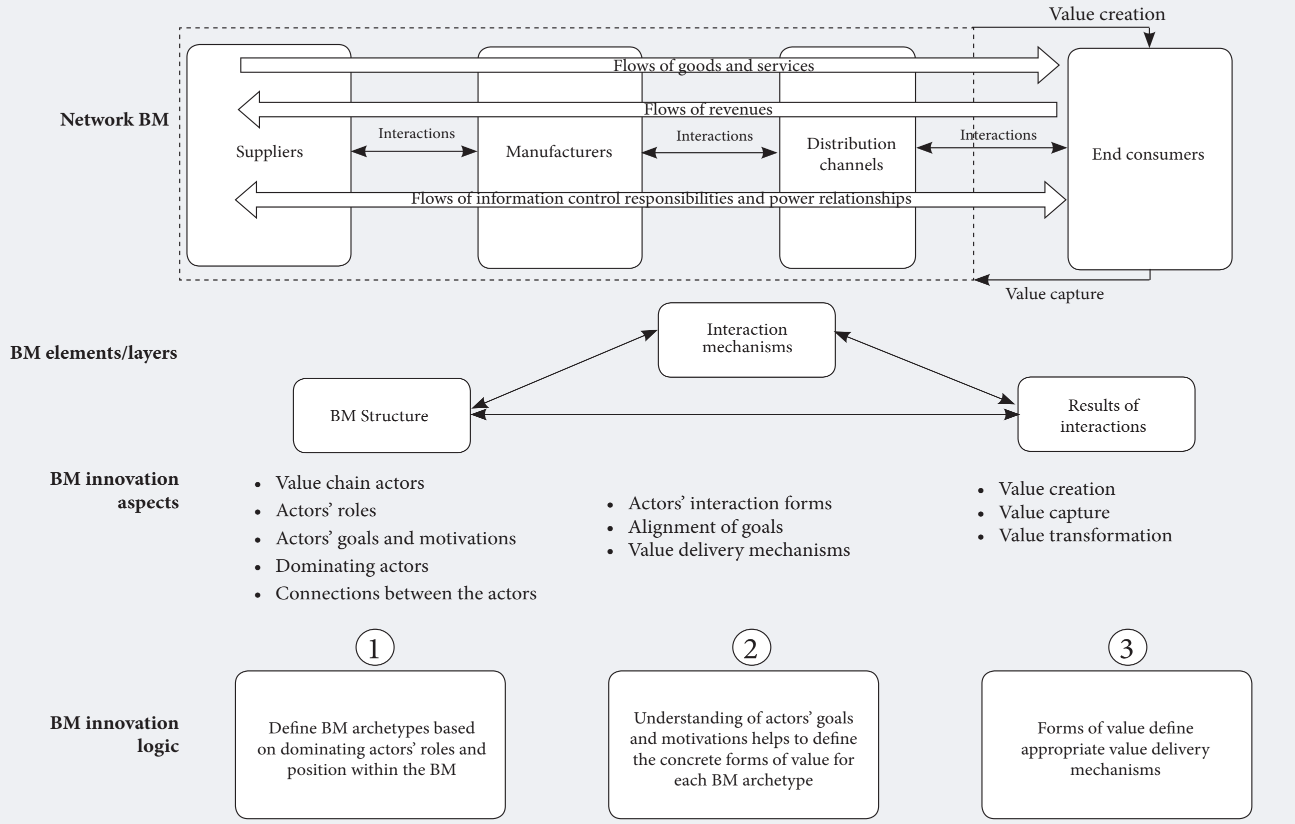
The three elements of BM include the actual structure of the BM, interaction mechanisms applied by BM actors, and the results of their interactions reflected in delivering value to the end consumers and also capturing a portion of that value as profits. The framework highlights the key flows between the actors, such as the flow of goods and services, the flow of revenues, and also flows of information, control, responsibilities, and power relationships, defining the particular ways in which value is created within the BM. Actors are linked by interaction mechanisms that identify how well the objectives of them are aligned and where there are gaps that need to be bridged to increase the value created for the end consumer and also the value captured by other actors in the form of revenue. Each of the key elements of the framework is described and followed by a number of BM innovation aspects, which represent specific opportunities to innovate BM in order to increase the value created for each of the actors and also for the end consumers.

Innovation opportunities within the BM structure include inclusion or exclusion of specific BM actors, defining their roles and responsibilities in the value creation process, defining their goals and motivations, defining dominating actors that play a key role in value creation and distribution, and also managing and optimizing the links and connections between different actors.

Interaction mechanisms between BM actors can be transformed and innovated by looking into concrete interaction forms that the actors are using, aligning their goals and motivations to eliminate potential conflicts that impact the value creation process, and also by changing the value delivery mechanisms used by the actors.

Finally, the results of interaction between BM actors reflected in the value created by the BM can be innovated by analyzing the processes of value creation, value capture, and value

Figure 1. **The Framework of BM Innovation**



Source: authors.

transformation. Here it is important to understand how to align the value processes with the needs of BM actors, including end consumers, which will enable them to receive higher value at a lower cost.

Because of the complexity of the contemporary business environment, a single company can simultaneously have multiple BMs, where each is characterized by their specific features. Hence, BM innovation logic starts by classifying BMs and combining them into specific archetypes based on the concrete dominating actors within the network. These dominating actors actively shape the BM structure and operating mechanisms, driven by their goals and motivations. Therefore, the logic is followed by understanding the goals and motivations of dominating actors, which define concrete forms of value that need to be created and delivered for each BM archetype. Finally, forms of value define appropriate value delivery mechanisms of channels that need to be applied by BM actors.

We further apply this framework to BM innovation to develop specific BM innovation mechanisms using the case of an international company operating on the pharmaceutical market.

Methodology

This paper presents a case study focused on an international company operating on the pharmaceutical market. The findings are based on internal company information and the application of a participatory observation method as well as on the recent research of companies focused on studying the pharmaceutical market (such as IQVIA, Synovate Comcon, Accenture, and PriceWaterhouseCoopers).

For the purpose of studying pharmaceutical BM innovation, we selected a number of markets, which represent different types of healthcare systems with different driving forces: Russia, Thailand, Ukraine, Chile, Israel, and Mexico. These countries are not only situated in very different parts of the world, but also differ by the interaction mechanisms between key BM actors (physicians, pharmacies, patients, and state healthcare authorities) establishing different types of relationships and value creation processes. Below we provide some key characteristics of these markets so that the differences can be better understood (Table 1):

Based on the data presented in Table 1, we can observe some key differences between the markets, which illustrate why these markets were selected for the study. Firstly, a difference comes from market structures in terms of public and private financing. Public financing implies that the market is financed by government healthcare institutions, while private means that it is driven by either end consumers or private institutions. Hence, on public markets, the dominating force driving market development are state healthcare authorities, while on private markets these are different actors, primarily end consumers or patients, who finance the market. Secondly, a difference arises from the market split in terms of the types of the products: Rx (prescription-driven products) and OTC (over-the-counter or non-prescription-driven products). On

Table 1. **Key Market Characteristics**

Characteristic/Market	Ukraine	Russia	Israel	Mexico	Chile	Thailand
Market size (bln USD)	3.4	17.9	2.12	10.4	2.6	5.6
Public/Private	13/87	34/66	91/9	19/81	38/62	75/25
Rx/OTC	61/39	48/52	93/7	80/20	80/20	80/20
Dominating actors	Pharmacies, patients	Pharmacies, patients	Physicians, state	Physicians, patients	Physicians, patients	Physicians, state

Source: authors.

Rx markets, a key role is played by the physicians, who primarily decide on therapies, which are prescribed to the patients. On OTC markets, the key players are pharmacies, who drive patients' purchase decisions as they can recommend non-prescription products. Finally, while situated in very different parts of the world, these markets are also very different in terms of their size, presenting different opportunities for companies to innovate their BM.

IIt is also important to mention that as the study was done on the basis of a specific international pharmaceutical company, we did it on a regional remit, following the geographical and organizational structure of the company. The company is divided into three regions, which include North America, Europe, and International markets (which includes everything except North America and Europe). We decided to focus on the most diverse region, which is the International market, to enable a further generalization of the outcomes. From a practical standpoint, the study was intentionally designed to help these markets analyze and transform their business models. Africa was not considered as the company studied does not have noticeable business there. It is also critical to mention that the markets selected for the study demonstrate a remarkable development of digital marketing, which can provide a good understanding of how digital BMs are constructed and executed.

In order to obtain specific BM innovation insights and qualitative characteristics of innovative changes within the BM, the authors ran structured interviews with the studied company's representatives. The results of the interviews were then processed to crystallize the findings. In each of the countries a senior marketing manager of the international pharmaceutical company was interviewed, a total of six in-depth structured interviews were conducted, recorded, and coded for further analysis. The questions were structured around the following topics in line with the framework for BM innovation outlined earlier and explore the structure of the BM, interaction mechanisms between BM actors, and the results of these interactions:

- Trends in the country that shape the development of pharmaceutical companies
- Critical needs of the market that should be addressed by the pharmaceutical companies to be successful in the long term
- Strategic gaps that a company has and ways to bridge them
- Key actors on the market and their priorities and needs
- Promotion channels used to market products to different types of actors and their development trends

The results of the interviews helped to define cross-country BM trends described further. These trends contribute to a better understanding of the forces driving BM transformation on different markets. The interviews also helped to identify the key combinations of BM actors, who drive the value creation process on each market. This helped to classify and visualize certain BM archetypes used further for assigning particular BM transformation mechanisms.

The questionnaire used for the interviews is provided in Box 1. The details on each market responses are provided in Table 2.

In the next sections, we will demonstrate how the BM can be innovated in practice using the new framework for BM innovation. To do that, we will start by exploring the trends that

Box 1. **Questionnaire for Interviewing Senior Country Marketing Managers**

1. Please describe the key market trends and characteristics that shape the development of pharmaceutical companies in your country: therapeutic areas, government initiatives, buying processes, and key decision makers.
2. What are the key needs of the market that you think have to be addressed in order to succeed?
3. Please describe your business priorities and key business lines for the next three to five years.
4. Where are the strategic gaps you feel you have between what you think is needed and where you are today?
5. Please describe key groups of customers that you interact with currently and how you think this will change in the future and why.
6. For each group of key customers please define their key priorities and needs that are to be addressed.
7. For each group of customers describe the current promotion channels that are used and how this will change in the future and why.
8. Please describe the purpose and perceived value of each promotion channel for you and your customers.
9. Please identify key market trends that will shape the transformation of promotion channels in your country.

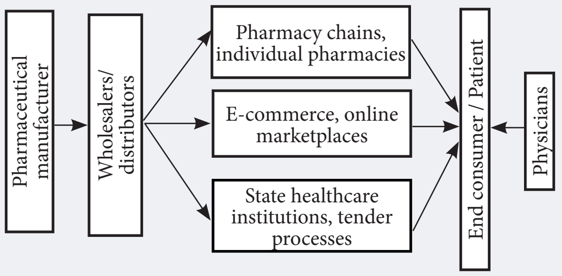
Source: authors.

Table 2. **Key Outputs from the Interviews of Marketing Managers on Each Market**

Interviewees	Key outputs from the interviews
Russia	
Trade marketing director Cardiology franchise director	• Pharmacy chains gain more power due to consolidation • E-commerce market is growing • Marketing budget of the company is not competitive • The company does not have a tailored approach to each pharmacy, activities are not customized, which creates a gap vs competition • Need to increase awareness about the company products among customers • Already do telemarketing on a large scale (10,000 pharmacies covered) • Key drivers of purchases in pharmacies are quality, availability, and assortment • Consumers become more demanding driven by experience on other markets • Consumers compare prices on the internet instead of visiting pharmacies physically • Many physicians have begun working remotely and providing telemedicine services • The company needs to find other, non-traditional ways of differentiation • There is a need to establish loyalty programs for patients • The influence of patients and pharmacies increases in decision making, wholesalers also become more powerful
Chile	
Senior director of marketing	• Three pharmacy chains occupy 90% of the market and are very powerful • It is critical to have presence in many target areas to be highly positioned on the market • Physicians' role and power is being transferred to pharmacy chains over time • Patients look for quality and compare prices • Time constraints for physicians limit face-to-face interactions • Limited opportunities for physicians to attend meetings • Digital marketing is positively perceived, especially by young physicians • It is critical to increase brand awareness among pharmacists • The e-market is small, but very attractive, however, face-to-face is still the most popular communication channel
Israel	
Sales and marketing director	• For prescription drugs physicians are the key decision makers, and face-to-face is the most popular channel • In the future, face-to-face communication will be a challenge, and already digital marketing is very broad: telephone calls, webinars, and video calls. Critical to have an integrated multi-channel approach. • Israel is a highly digital market: 70% of physicians use smartphones for professional reasons • Patients' role becomes the key not only in the non-prescription (OTC), but also in the prescription (Rx) segment • Pharmacy chains increase their power • Competition between pharmacies will increase due to new healthcare regulations • E-commerce grows and creates price pressure for manufacturers • Pharmacies are interested in better pricing and commercial cooperation, as well as in improving the professional skills of staff. • Patients become more active in their decisions, empowered by online tools • Companies need to be faster and more responsive to customer needs, more personalized content is needed
Mexico	
Senior sales director	• Government saves money and lowers the costs • Mexico is a brand-driven market, there is need to support strong brand equity in retail • Upper- and middle-class pharmacies are the key focus • Physicians are the key decision makers for prescription drugs • Pharmacies also generate prescriptions, which helps the government to release capacity • Need to be on parity or outpace competitors' presence • Face-to-face is still very popular and there are no big risks of losing it in the future
Ukraine	
Business unit director Commercial excellence director	• Broad product portfolio and available marketing budget are key to success • Pricing and distribution should be competitive to succeed • Companies use new channels of communication more frequently • Branded generics promotion is a priority for the Ukrainian market, which are perceived as affordable products with added value • Pharmacists increase their power due to the ability to provide product substitution to the patient • E-prescription starts to be developed in a reimbursement channel and will be INN-based (International Nonproprietary Names) • The e-commerce market segment is small, slowed down by existing legal limitations • Low penetration of smartphone use for doctors limits opportunities for digital channels • Direct mail communication channel is very promising for the customers
Thailand	
General manager	• The market consists of hospitals, private clinics, and pharmacies • Clinics are visited mostly in urban areas and the overall coverage is not high • Pharmacies are mostly individual businesses and chains represent a small proportion of revenue, but they are growing • There is a growing need for digital promotion expansion, supported by the growing number of smartphones per capita • A more efficient ordering process for the hospitals is required • More value should be generated for physicians who have less time for face-to-face interactions and whose share is growing • The business in Thailand is mostly driven by rebates and personal relationships
Source: authors.	

shape BM transformation. Then we will focus on defining market archetypes characterized by different dominating actors that shape the "rules of the game" on each market – physicians, pharmacies, patients, and state healthcare authorities – which show the different configurations of the value chain that need to be addressed. Finally, we will classify BM innovation levers demonstrating different interaction mechanisms between the BM actors, focused on increasing the value for key BM actors via applying innovative marketing tools. These tools will be aligned with the market archetypes to define the opportunities that can be used by various markets to innovate their BM depending on the archetype it belongs to, by bridging together technological innovations and managerial technologies used to implement them in practice.

Figure 2. **Key Pharmaceutical BM Actors**



Source: authors.

Understanding Pharmaceutical BMs

Before studying the trends for technological development, marketing, and the specifics of pharmaceutical BM innovation, it is critical to understand how this BM looks, who are the key players there, and what roles they fulfill (Figure 2). The arrows demonstrate the directions of commodity movement between the actors.

Between the pharmaceutical manufacturer and the end consumer there is a set of critical market players that influence which product will finally be purchased by the patient. The level of each actor's importance significantly depends upon the market and product specifics, however, in general we can highlight the following key BM actors: physicians, pharmacies, state healthcare authorities, and end consumers (patients). Below we will characterize each of them in more detail.

Physicians – these BM actors play a key role on the markets, where the majority of the products is sold with a physician's prescription. Physicians recommend a specific product to patients, based on his or her needs, which the patient in turn purchases at the pharmacy. Physicians' influence is stronger on those markets, where pharmacies do not have the ability to substitute the product for the patient (as pharmacies can substitute in the case that, for example, the prescriptions are made using the molecule name and not the brand name).

Distribution channels include wholesalers, pharmacies, and online marketplaces. While each of them plays an important role, we will focus here specifically on pharmacies, as they connect directly with the end consumers and capture the majority of the sales on the market as e-commerce and online marketplaces still represent a small share of sales even considering the impact of COVID-19. Pharmacies play an important role especially on the markets with a large share of non-prescription (OTC) products, where products can be purchased without a prescription, or if the prescription can be refilled without a physician's participation. Also, pharmacies' influence is high if they have the ability to substitute products prescribed initially by physicians.

The state healthcare system plays a crucial role on the markets where a large share is state financed. On those markets, usually the key customers are the state healthcare institutions and the purchases are done using a tender process, when a certain number of manufacturers compete for supplying a higher quality product with a lower price.

End consumers (patients) play a key role on the markets that are financed out-of-pocket, using the end consumer sources (retail markets), and also on the markets with a large share of non-prescription products, where the patient can personally make decisions on the products he or she would like to purchase.

Global Trends that Shape the BM Transformation

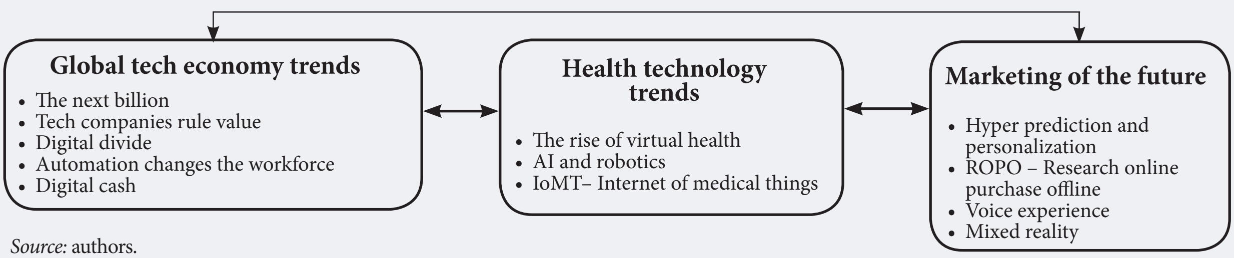
Given the nature of changes that happen in the contemporary world, we should first understand the key drivers forcing the companies to transform their BM. The effect of the COVID-19 pandemic has dramatically accelerated the technological transformation of the economy. This in turn forced companies to innovate their BM and implement new managerial technologies. Our analysis demonstrates that these drivers, or trends, can be divided into three major categories (Figure 3):

First trends to focus on will be the global digital trends that will shape the economy and drive its transformation:

1. The next billion consumers who come online will mostly come from emerging market countries [*Arora,* 2019]. They will access the Internet using their mobile devices, which will dramatically change the way they do business and commerce and how they consume content.

2. Technology companies now rule value across the globe [*Chakravorti et al.,* 2017]. Apple, Alphabet, Microsoft, Amazon, Facebook, and Alibaba are the most valuable companies in the world today. The importance of tech companies became even more significant in 2020 with the significant

Figure 3. **Trends in the Economy, Technology, and Marketing that Drive BM Transformation**



Source: authors.

shift in customer habits. For example, Accenture highlights that more than 50% of consumers are uncomfortable visiting public places, at the same time they use and expect to continue using home delivery, in-app ordering, and virtual consultation [*Standish, Bossi,* 2020]. Some of the technological companies that will benefit from significantly increased demand for their services show triple digit growth in stock price, according to Nasdaq[4], such as Zoom (+528%), Docusign (+188%), Square (+221%), and Twilio (+192%).

3. Digital divide, which primarily means that markets are uneven in terms of digital development [*Kemp,* 2019]. Almost 50% of the world is still not online, which creates a lot of potential, but also provides a big gap that businesses need to bridge in order to provide everyone with the same opportunity to enjoy online commerce and content. This trend is also reinforced by the research from Tufts University [*Chakravorti, Chaturvedi,* 2018], which demonstrates how different countries can be classified on the basis of a so-called digital evolution index. This index groups 60 countries into four categories based on their digital advancement (reflected in the level of e-commerce development, quality of digital infrastructure and regulation) and the rate of growth since 2008.

4. Automation that changes the workforce. There are around one billion jobs around the world that can be replaced by automation and that can save about 15 trillion USD in wages. Within that time more roles and functions will be automated, which will dramatically change the business landscape over the next few years [*Chakravorti, Chaturvedi,* 2018; *Chakravorti et al.,* 2017].

5. The growing use of digital cash. At the same time, most of the world still works with traditional cash as a main source of payment, which should be contended with in order to bring e-commerce to a much broader level especially on emerging markets [*Chakravorti, Chaturvedi*, 2018; *Chakravorti et al.,* 2017].

The next group of trends relate to healthcare technology, which will significantly affect all the key actors in the pharmaceutical business – consumers, physicians, pharmacies, and the government. They are extensively described in a recent report prepared by the Deloitte Center for Health Solutions called "Medtech and internet of medical things: how connected medical devices are transforming healthcare" [*Ronte et al.,* 2018]:

1. The rise of a virtual health. Virtual health relates to health services that are provided through non-personal ways of contact, such as video, phone, or health applications. These new ways of interaction will change market models for healthcare – e.g., how patients pay for healthcare, and how much availability doctors have. A recent IPSOS study demonstrates that telemedicine use was increasing sharply in 2020 and the shift has happened quickly – 80% of physicians are already using telemedicine [*King et al.,* 2020].

2. Artificial intelligence (AI) and robotics. AI and big data analytics are already changing the way healthcare systems do diagnostics. While robotics is gradually making some jobs redundant, new jobs also evolve that require a combination of and interaction between employee skill sets and transferrable skills.

3. Internet of medical things (IoMT) is defined as a connected infrastructure of medical devices, software applications, and health systems and services. This trend significantly impacts the transformation of relationships within the healthcare system and the value that is brought to various actors. This happens primarily because establishing connectivity between medical devices and systems helps clinicians streamline their work processes, which enables one to provide better care for patients.

A lot of changes in healthcare technology are also triggered by the recent impact of the COVID-19 crisis. Recent IQVIA research demonstrates that the needs of the key pharmaceutical BM actors are dramatically changing. Examples include: longer prescriptions in retail pharmacies, in terms of the number of days of prescription medication that are available at once so renewals need to be more infrequent; treatments for chronic illness could see declines in treatment initiation and switch because these require a healthcare professional's intervention; stocking up effects are possible, where patients are on chronic medications for long term conditions, such as diabetes or cardiovascular patients anticipating isolation or are reluctant to visit healthcare facilities [*Rickwood,* 2020].

The final group of trends describes the ways and means of marketing transformations. The recent research by Deloitte states that every fourth pharmaceutical company reports having implemented a digitally driven strategy or being in the process of doing so.[5] Another 46% are in the process of developing such a strategy. This highlights the growing attention toward finding the new, complementary marketing channels that can be used by companies to improve their interaction with customers and also make it more cost effective. In particular, these trends include:

1. Hyper prediction and personalization. The data that companies collect on their customers, mostly in a digital way, will impact the way they bring content and value propositions. This can be done in much more precise and personalized way, as personalization allows a firm to know the customers much better and to understand what they expect from the companies at each stage of their interaction [*Rust,* 2020]. Recent studies demonstrate that considering the changing customer landscape and needs, this is a good opportunity to revisit customer segmentation to better meet changing demand [*Cowan,* 2020]. This includes understanding if the existing customer segments are still valid, if products and services fulfill the 'jobs to be done' by your consumers, and if the positioning and messaging still resonate with the consumers.

2. Research Online Purchase Offline (ROPO). This trend describes the pattern when consumers buy offline after conducting thorough online research[6]. This affects the way companies manage their data and content online so that their patients, physicians, and other key groups of customers can find the necessary information.

3. Voice experience. Today most of the users' experience with computers and digital modes is triggered by writing informa-

[4] https://www.nasdaq.com/market-activity/stocks/, accessed 14.06.2021.

tion, but gradually it has changed into voice commands. The way people speak and write is very different, which will affect the way research is done online and the content that is provided back to the users in response to their requests[7] [*Roy,* 2019].

4. Mixed reality. It can be decomposed into virtual and augmented realities [*Flavian et al.,* 2019]. Virtual reality describes an experience when a person fully disconnects from the real world and immerses him- or herself in a virtual world, where one can interact with virtual objects. And in case of augmented reality, a digital layer appears above what is seen in the real world, augmenting the real experience of a person.

Cross Country Trends and Market Archetypes

As was demonstrated above, the global trends in technology and marketing are critical to understand in order to shape commercially successful BMs in an optimal way. However, as a BM primarily deals with the creation of value through the interaction of different market actors, it becomes specifically relevant to study and understand also the specific features of the healthcare system and the pharmaceutical market's characteristics, which define the interaction principles for various actors and influence the value creation process. These would definitely vary across markets, as countries represent different development levels of the healthcare system and varying roles of actors as well as their relative power and influence.

Five cross-country market trends were highlighted as a result of a complex study of the changes happening in the value chain, including interviews with senior marketing executives. It is critical to understand that digitization concerns all the actors of the value chain as well as the BM innovation process. Along with that, it is critical to explore how this digitization process can be effectively implemented in practice using managerial technologies and considering the specifics of the companies, which will implement the changes.

Development of an e-commerce market. While the e-commerce market can still be very small (e.g. in Russia it occupies only 2% share of the total pharmaceutical market, according to IPSOS [Feldman, 2018]), it grows rapidly and its growth is also facilitated by growth in other sectors of the economy, i.e., when consumers increase the share of their wallet spent online, it is usually increased across most of the goods that they typically consume. The implications of this trend are definitely significant for market players and this compels pharmaceutical companies to reassess different elements of the BM along the value chain. In addition, e-commerce market development shifts the power from traditional pharmaceutical retail to e-pharmacies and electronic marketplaces, forcing incumbent players to adapt to the new reality (primarily wholesalers and large pharmacy chains). This shift was especially active in 2020, when the share of e-commerce significantly increased due to various restrictions, changing ways of life, and limited mobility of the population – for example, in Russia the sales of online pharmacies are expected to triple in 2020 vs 2019 [*Rockwood,* 2020].

Increasing digitization of consumers. This trend is expressed in many ways in a number of countries, e.g., Chile is among the top countries in Latin America in terms of smartphone penetration.[8] In Russia, according to recent IPSOS research [*Feldman,* 2018], the key information source for the pharmacist is the Internet, and face-to-face meetings with pharmaceutical sales representatives are only in second place. In Israel 70% of the physicians regularly use smartphones for professional reasons.

Increase of the patient's role in the decision-making process. Consumers gradually become more demanding driven by their experience outside the pharmaceutical market. When patients are looking for the optimal treatment solution, it is easier for many of them to search for the drugs and compare prices on the Internet than physically visiting several pharmacies, which is also facilitated by the development of delivery services. Digital means provide easier and more transparent access to the information, which increases competition between various market players and forces them to better address customer needs. Recent research from EY also demonstrates that patients become "super consumers" as they make decisions based on a holistic assessment of the alternatives coupled with reduced purchasing power[9] [EY, 2021].

Consolidation of pharmacies and the increasing role of pharmacy chains. The importance of a pharmacy as an actor is hard to underestimate on many markets. Pharmacy chains increase their power when they grow their share on the market vs individual pharmacies. A pharmacy chain is a group of pharmacies consolidated under a single owner, which makes them work through buying decisions centrally. For example, in Russia, the value share of pharmacy chains is already more than 80%. In Chile, the top three pharmacy chains occupy 90% of the market [*Rickwood,* 2020]. Also on the markets, where pharmacists have significant drug substitution ability, pharmacies also play a key role as they in most cases influence which drug a patient will actually buy. These factors form a need for developing new tools and ways of increasing value created for pharmacies by pharmaceutical companies.

Decreasing access to physicians by pharmaceutical companies. This factor creates pressure for pharmaceutical companies on many markets, as it limits interaction opportunities between doctors and pharmaceutical companies, which are still the key element in the promotion process of drugs. This forms a need to develop new and effective methods for interactions between manufacturers and physicians that respond to existing challenges. This trend became especially visible in 2020, when due to the COVID-19 pandemic personal interactions of all types were minimized unless absolutely necessary. Recent studies demonstrate, however, that physicians' need for information and support remains, and data shows an in-

[5] https://www2.deloitte.com/ru/en/pages/life-sciences-and-healthcare/articles/russian-pharmaceutical-market-trends.html, accessed 17.06.2021.

[6] https://www.thinkwithgoogle.com/marketing-resources/online-research-driving-offline-purchase-for-gortz/, accessed 17.06.2021.

[7] https://brandequity.economictimes.indiatimes.com/news/marketing/marketing-in-2025-five-key-trends-that-will-drive-the-future/72208376, accessed 17.06.2021.

[8] https://newzoo.com/insights/rankings/top-countries-by-smartphone-penetration-and-users/, accessed 17.06.2021.

[9] https://www.ey.com/en_kz/digital/how-health-care-companies-can-capture-value-in-the-future, accessed 17.06.2021.

Table 3. **Four Market and BM Archetypes**

Main Actors	Description
Archetype 1. Physicians, Patients	• Mainly OOP markets where physician plays the key role in purchase decisions • Products are prescribed using brand name and not INN • Limited ability of a pharmacist to substitute • Countries with dispensing physicians, who supply patients directly with medications letting them bypass pharmacies
Archetype 2. Pharmacies, Patients	• Purchase decisions are highly influenced by the recommendation of pharmacist, and the key financing source is OOP of the patient • Large share of the market is represented by OTC products • High level of self-medication • Prescriptions can be done by INN and not brand name • Significant substitution ability of a pharmacist • Many prescription products are actually sold without the prescription / renewed without physician involvement
Archetype 3. Physicians, State healthcare authorities	• Predominantly state-financed markets where physician plays the key role in purchase decisions • Markets dominated by state / hospital / reimbursement channel • Markets where the majority of the products are purchased through state and institution regulated tender process (products are selected based on prise level and supply reliability) • Doctors prescribe products included into the hospital›s formulary, and also influence formulary decisions
Archetype 4. Pharmacies, State healthcare authorities	Mainly state-financed markets with full substitution between generics, where decision on the product is made by pharmacist
Source: authors.	

crease in remote interactions. The question now, of course, is which type of remote engagement is appropriate and when [*Rickwood,* 2020].

Based on the research presented above as well as considering the modifications of the value chain for the international pharmaceutical company studied in this paper and operating on different markets, we crystallized specific BM archetypes. The archetypes will be used to group managerial strategies for BM innovation. The archetypes are based on combinations of key actors who drive the value creation process. It is critical to mention that within a single market there could be multiple BMs at the same time, based on the product specifics, promotion model, and structure of the value chain. Here with examples below we highlight the most common attributes that we found on the basis of respondents' answers (Table 3)/

The first archetype includes the markets dominated by **physicians and end consumers (patients)** (Mexico, Chile). The key financing source for this archetype is mainly patient's own money while government financing does not play a key role here. On these markets, the physician usually plays a key role in defining which drug patients will buy at the pharmacy. Accordingly, these markets are usually dominated by prescription (Rx) drugs, which means that in order to purchase a drug, a patient should first obtain the prescription from the physician. On these markets, products are usually prescribed using the brand name and not INN (international non-patented name), which creates limits opportunities to substitute the drug at the pharmacy when patient comes to buy.

The second archetype describes the markets dominated by **pharmacies and patients** (Russia, Ukraine). These are typically the markets with a large share of non-prescription (OTC) products, which significantly reduces the role of the physician. Also, on these markets we can observe a high level of self-medication where patients make treatment decisions on their own bypassing the physician's office. If the patients do go to the physician's office, the products are typically prescribed by INN and not by brand name, which provides the pharmacist with the opportunity to choose within INN. We also can attribute to this archetype those markets where prescription drugs are actually sold without prescriptions or where the prescriptions can be renewed without a physician's involvement.

The third archetype represents markets dominated by **physicians and state healthcare authorities** (Israel, Thailand). These markets are typically dominated by a state/hospital or reimbursement channel. All these types of channels require a financing source to come from state resources. Because of that, on markets of this type there is a significant share of state tender business regulated through state and state healthcare institutional processes, when the government purchases large amounts of pharmaceuticals based mainly on price and supply reliability so that the manufacturer offering the lowest price and good supply conditions can win the tender. On these markets, physicians' prescriptions are usually guided by fixed lists of drugs (formularies) approved for use by healthcare institutions.

The final archetype are the markets dominated by **pharmacies and state healthcare authorities**. These are primarily state-financed markets with full substitution between generics, where the purchase decision is dominated by pharmacists.

Digital Promotion Levers and Value Transformation within the BM

By studying the existing top performing market practices discussed in detail in both professional and academic literature [*Ramgaswamy, van Bruggen,* 2005; *Kushwaha, Shankar,* 2013; *Sharma, Mehrotra,* 2006; *Mukherjee, McGinnis,* 2007] and also considering the results of interviews with marketing executives conducted within the current study, we have identified six digital promotion levers that can be implemented to drive changes within the BM focused on value generation. These levers are spread in varying degrees across the pharmaceutical market, while some of them are already extensively used and some are simply discussed and not very widespread across companies and markets. By value generation we first of all understand this term as the introduction of a new or improvement of existing promotion practices that allow for bringing meaningful contributions for how to best address customer needs as well as how to improve the commercial success of different commercial BM actors.

Channel mix optimization. This lever describes using data and platforms to drive the right channel mix through smarter customer segmentation and journey creation, reducing the cost per engagement and maximizing the lifetime value of customers. The recent IQVIA study demonstrates that the disconnect between what healthcare professionals say they want in terms of channels and what they get is much more common than convergence [*Dabbs et al.,* 2018]. However, the selection of an appropriate promotion channel usually depends not only upon the customer preference, but also on the relationship between the cost of the channel and revenue that can be generated by implementing the channel. This means that the customers who have higher business potential (e.g., doctors with more patients) can be addressed by more expensive and personalized channels (e.g., in-person promotion), while low potential customers or customers that cannot be reached personally are approached by low-cost promotion channels, such as emailing or virtual detailing [*Grosch et al.,* 2014]. Also, the application of a specific channel will depend on the purpose. In this sense, face-to-face communication with customers is usually used in order to convey a complex message, launch a new product, or when high conviction is needed. On the other hand, e-mails are usually used for a different purpose, such as medical and brand updates or invitations to conferences. The transformation of value is driven by channel mix optimization in a number of ways. First, it extends customer reach and the frequency of interactions due to increasing the number of ways of how a customer can be approached by the company. Second, it helps to increase sales per customer engagement due to customizing the promotion process to meet individual customer needs. Third, it drives lower cost per engagement, as enriching personal communication with digital promotion tools, which are less costly, helps to decrease overall promotion expenses.

Virtual (remote) selling approaches. This is a promotion channel, which increasingly starts to be applied by many pharmaceutical companies in order to reach more customers, who cannot be reached in a regular face-to-face setting. Remote selling is done by using special tools and platforms usually integrated with company CRM systems and this approach allows both the customer and the company to have a close to personal interaction experience, while also offering several benefits over personal communication. Those benefits include more convenient scheduling of appointments because the meeting can happen at any convenient time for the customer and also outside of working hours, the discussion becomes more practical, the meeting can usually last longer than traditional personal meetings as it better fits the customer's schedule [*Dabbs et al.,* 2016]. At the same time, virtual communication with customers should not be considered a replacement for traditional ways of communication, but more as an additional channel. A BCG study demonstrates that digital methods are complementary to face-to-face and their impact is not limitless: physician participation rates in purely digital marketing campaigns average only 2% to 5% and also less than 15% of physicians agree to receive detailed phone calls from call centers [*Grosch et al.,* 2014]. The value transformation is affected by this lever in two major ways. Firstly, it is done by extending customer reach and frequency by complementing the existing promotion mix and enabling access to more customers. Secondly, it generally allows for lowering cost per engagement, as by applying good scheduling practices, this lever allows one to have more high-quality interactions with customers in comparison to in-person communication.

Digital consumer demand generation. This lever primarily deals with utilizing new forms of digital and social media to generate consumer awareness and demand for products or awareness of disease areas. The specific importance of digital consumer demand generation is visible on the markets where consumers play a key role and have strong decision-making powers – primarily these are the markets where the out-of-pocket segment occupies a large share and also the markets where a large share is occupied by OTC (non-prescription) products. There are many markets where physicians stated that their patients' involvement in the decision-making process has increased significantly. This is also driven by the increased exposure of consumers to information published on the Internet, which helps consumers compare treatment alternatives and make an informed choice. The value transformation is done through three key areas. Firstly, it is improved media spend efficiency, which is important especially for OTC products, where advertising and direct contact with consumers is usually a key promotion investment area. Secondly, this also triggers disease area market growth, as generating more knowledge about a disease among consumers drives their demand for medicines. Finally, this also stimulates improved adherence to the therapy among the consumers, which is very critical for business success.

Self-service and B2B e-commerce. This lever allows customers (primarily pharmacies or dispensing physicians, who sell medicines to the consumers) to self-serve business-to-business needs, by freeing time from sales and customer service teams and reducing costs. This lever also implies the development and utilization of a business-to-business e-commerce platform, that allows for cross and up-selling opportunities and the improvement of customer reach. The commercial actors of pharmaceutical BM are key targets for this lever, as they participate in the selling process and are interested in both increasing their profitability level as well as in simplifying ordering and selling processes. E-commerce platforms allow for achieving both goals by implementing flexible discount mechanisms and also by introducing user-friendly ordering systems that are convenient for customers.

Smart product recommendations. This lever deals with increasing the demand for profitable products by providing recommendations that fit customer needs via automated algorithms. These recommendations also take into account multiple factors, such as product availability, competitors' activities, and the profitability of products. The recommendations are produced by customized software that is developed to reflect the customer buying process and be compatible with systems and tools that are already used by the customer to make a purchase, including business and physical customers.

Table 4. **Digital Promotion Levers and Value Transformation Mechanisms**

Digital promotion lever name	Definition	Value transformation mechanism
Channel Mix Optimization	Using data and platforms to drive the right channel mix through smarter customer segmentation and journey creation, reducing the cost per engagement and maximizing the lifetime value of customers	• Extending customer reach and frequency • Increased sales per customer engagement • Lower cost per engagement • Increased profitability
Virtual (Remote) Selling Approaches	The execution of remote selling models to drive higher efficiencies and the productivity of sales force	• Extending customer reach or frequency • Lower cost per engagement
Digital Consumer Demand Generation	Utilizing new forms of digital and social media to generate consumer awareness and demand for products or awareness of disease areas	• Improved media spend efficiency • Disease area market growth • Adherence improvements
Self-Service and B2B eCommerce	Allowing customers to self-serve B2B needs, freeing time from sales and customer service teams (reducing cost to serve). Drive applicable business to e-commerce platform to allow for cross and up-selling opportunities and improvement of reach.	• Increased sales per customer • Extending customer reach and frequency • Lower cost per engagement
Smart Product Recommendations	Increasing the demand for profitable products by using automated product recommendations based on customer needs, product availability, competitive intelligence, and profitability of the product	• Increased sales per customer • Higher profitability
Automation to Drive Effectiveness	The use of decision support to drive next best actions and process automation for sales force and marketing in order to optimize sales and marketing costs	• Increased sales per customer

Source: authors.

Automation to drive effectiveness is related to automated systems and algorithms that are developed to drive the next best actions and the automation of processes for sales force and marketing to optimize costs and revenues. The automated algorithms leverage multiple types of customer data to increase sales and reduce promotion costs for different customers. This can be done in the form of optimizing content recommendations, for example.

We summarize each digital promotion lever's characteristics and value transformation features below (Table 4).

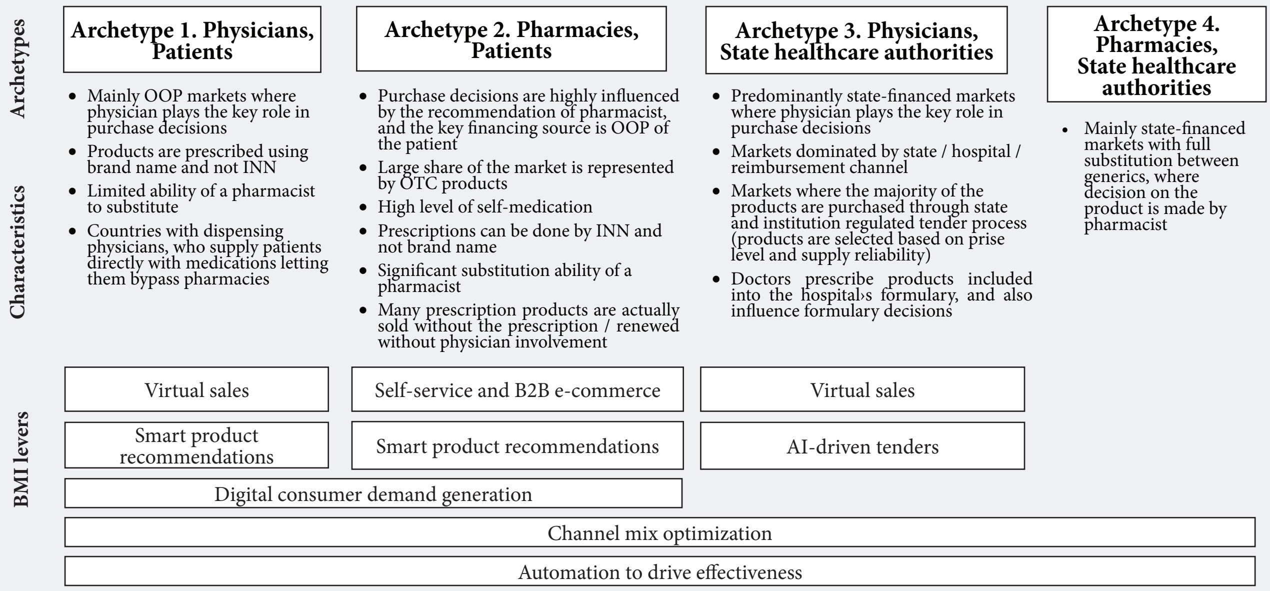
As a result of the definition of digital promotion levers and understanding the benefits and mechanisms of each of them, as well as considering the results of the literature review, participatory observation of the authors, and the analysis of the case study, we aligned them with market archetypes described earlier to demonstrate how different value creation mechanisms fit with different actors' needs (Figure 4). Following the framework for BM innovation described earlier, these digital promotion levers represent specific interaction mechanisms between BM actors that influence the results of interaction. The key objective is to develop a BM that will effectively create value along the value chain and will not fail through the collective interaction of its actors.

The physician- and patient-driven market archetype requires the levers that will primarily be able to impact the value generated for the physicians and for patients (end consumers), who act as two key driving forces of this market. These levers will enable key actors to obtain the required information to make decisions faster and in a more convenient way. Hence, the levers, which are uniquely fit for this type of market are virtual sales and smart product recommendations. Virtual sales are primarily targeting physicians, who are not targeted by traditional face-to-face promotion, or this approach can augment the existing interactions between pharmaceutical manufacturers and physicians by adding additional touchpoints for their interactions. By using the virtual sales approach, physicians can interact with manufacturers and receive necessary product and therapy information in the most convenient way, which does not distract them from daily work. Many physicians also mention that they see this format of interaction as more valuable than face-to-face and that it allows one to better concentrate on the topic at hand. Smart product recommendations are suitable for both patients and physicians whenever they are looking for the specific product or therapy that fits their needs. This lever helps consumers find appropriate solutions more rapidly and in a more effective way.

The pharmacy- and patient-driven market archetype is focused primarily on delivering value to pharmacies and end consumers, who act here as the key decision makers. The levers, which generate the value for these types of actors, include self-service and B2B e-commerce as well as smart product recommendations. B2B e-commerce is a critical value generating mechanism used with pharmacies, who want to optimize their buying process and make it easier and more automated and tailored to their needs based on past purchase history and the preferences of a specific pharmacy. This usually comes in the form of tailor-made solutions, which can also apply various discount schemes in order to increase sales volumes and pharmacy loyalty to company products.

The physician- and state healthcare authorit7-driven market archetype is guided by the state procurement processes and mechanisms and therefore value generating levers should be focused here on optimizing the tender process in order to supply the government and patients with high-quality therapies and optimal prices. Therefore, the lever differentiating this market archetype is AI-driven tenders, which are based on automated tendering algorithms, which optimize the price of a particular manufacturer over competitors' bids and allow manufacturers at the same time to maximize their profits. In many countries, the tender processes in healthcare are very

Figure 4. **The Alignment between Market Archetypes and Business Model Innovation Levers**



Source: authors.

frequent and are done on a significant scale, therefore manual bidding does not allow for maximizing profits and winning rates, while such processes also take too much time.

The channel mix optimization and automation to drive effectiveness business model transformation levers are suitable for each market archetype as they can be applied to satisfy the needs of any customer type, whether it is a pharmacy, physician, or the state healthcare authorities. Digital consumer demand generation is applicable for both physician- and pharmacy-driven out-of-pocket market archetypes, as they are primarily guided by the patient, who is a key decision maker in these market archetypes.

Conclusion

The current paper demonstrated how technological innovations should be applied in practice using managerial technologies and insights to drive BM innovation along the value chain. We focused on the case study of an international company operating in different geographies within the pharmaceutical market and on the innovation strategies at the corporate level. The BM adaptation to the specifics of different markets is forced by the differences in the value chain and key BM actors, who dominate the market and therefore significantly influence the value creation process.

It is critical to acknowledge that technological innovation comes to the next level given the rapid changes in the ways companies do business imposed by the COVID-19 pandemic. As it was demonstrated, companies have been forced to reassess the whole set of interactions with their customers driven by changing customer priorities and needs. In this sense, looking at the BM innovation process though the marketing perspective becomes especially important as it defines what should be the value delivered to the customers to meet needs and make the company commercially successful. Based on that, this paper demonstrated how to combine managerial technologies with the increasing digitalization of the BM and how to classify BM innovations based on market specifics.

The new framework for BM innovation presented in this paper understands BM broadly on an organizational network level, spanning the boundaries of a single firm and it allows for decomposing the BM innovation process by looking at key BM elements (BM structure, actors' interaction mechanisms, and the results of those interactions) as well as the BM innovation aspects linked to each element. It also outlines a BM innovation logic by archetyping BM based on dominating actors' characteristics, defining concrete forms of value for each archetype, and value delivery mechanisms.

The framework was applied to illustrate the BM innovation case study on the pharmaceutical market. Following the results of a literature review, the participatory observation of the authors within the studied company, and interviews with senior marketing executives, we demonstrated how the BM can be classified into archetypes based on different configurations of the value chain and dominating actors. The archetypes allowed the authors to group the managerial strategies for BM innovation that are required to further classify digital promotion levers and align them with different configurations of the BM to show how value can be created considering specific customer groups and their needs. The essence of BM innovation was demonstrated through the transformation of interaction mechanisms between BM actors reflected in crystalizing digital promotion levers and aligning them with each market archetype. This provides managerial insights on how to develop a BM that will effectively create value along the value chain and will not fail during the collective interaction of its actors.

The study was implemented in the framework of the Basic Research Program at the National Research University Higher School of Economics (HSE University) in 2021.

References

Amit R., Zott C. (2012) Creating value through business model innovation. *MIT Sloan Management Review*, 53(3), 41–49.

Arora P. (2019) *The next billion users: Digital life beyond the West*. Cambridge, MA: Harvard University Press.

Chakravorti B., Bhalla A., Chaturvedi R. (2017). 60 Countries' Digital Competitiveness, Indexed. *Harvard Business Review*, July 2017. https://hbr.org/2017/07/60-countries-digital-competitiveness-indexed, accessed 08.07.2021.

Chakravorti B., Chaturvedi R.S. (2018) *Digital Planet 2017: How Competitiveness and Trust in Digital Economies Vary Across the World*, Medford, MA: Tufts University. https://sites.tufts.edu/digitalplanet/dei17/, accessed 08.07.2021.

Chesbrough H. (2007) Business model innovation: It's not just about technology anymore. *Strategy and Leadership*, 35(6), 12–17. https://doi.org/10.1108/10878570710833714

Chesbrough H., Rosenbloom R.S. (2002) The role of the business model in capturing value from innovation: Evidence from Xerox Corporation's technology spin-off companies. *Industrial and Corporate Change*, 11(3), 529–555. https://doi.org/10.1093/icc/11.3.529

Cowan L. (2020) *COVID-19: Time to revisit customer segmentation* (Cicero White Paper), Washington, D.C.: Cicero. https://cicerogroup.com/covid-19-time-to-revisit-customer-segmentation/, accessed 08.07.2021.

Dabbs G., Rickwood S., Smith A., Wooden C. (2018) *Channel preference versus promotional reality* (IQVIA White Paper), Durham, NC: IQVIA. https://www.iqvia.com/-/media/iqvia/pdfs/library/white-papers/channel-preference-versus-promotional-reality.pdf, accessed 08.07.2021.

Ehret M., Kashyap V., Wirtz J. (eds.) (2013) Business models: Impact on business markets and opportunities for marketing research. *Industrial Marketing Management*, 42(5), 649–655. https://doi.org/10.1016/j.indmarman.2013.06.003

Evans S., Vladimirova D., Holgado M., Van Fossen K., Yang M., Silva E.A., Barlow C.Y. (2017) Business model innovation for sustainability: Towards a unified perspective for creation of sustainable business models. *Business Strategy and the Environment*, 26(5), 597–608. https://doi.org/10.1002/bse.1939

Feldman O. (2018) *Global views on healthcare – 2018: What does the world think about healthcare?*, Washington, D.C.: IPSOS Global Advisor. https://www.ipsos.com/sites/default/files/ct/news/documents/2018-08/node-455221-455431.zip, accessed 08.07.2021.

Flavián C., Ibáñez-Sánchez S., Orús C. (2019) The impact of virtual, augmented and mixed reality technologies on the customer experience. *Journal of Business Research*, 100, 547–560. https://doi.org/10.1016/j.jbusres.2018.10.050

Foss N.J., Saebi T. (2017) Fifteen years of research on business model innovation: How far have we come, and where should we go? *Journal of Management*, 43(1), 200–227. https://doi.org/10.1177%2F0149206316675927

Gatignon H., Lecocq X., Pauwels K., Sorescu A. (2017) A marketing perspective on business models *Academy of Marketing Science*, 7(3–4), 85–89. https://doi.org/10.1007/s13162-017-0108-5

Grosch B., Gupta A., Lucke J., Voller S. (2014) *Breaking through the noise: Pharmaceutical multichannel marketing in a digital world*, Boston, MA: Boston Consulting Group.

Hynes N., Elwell A.D. (2016) The role of inter-organizational networks in enabling or delaying disruptive innovation: A case study of mVoIP. *Journal of Business and Industrial Marketing,* 31(6), 722–731. https://doi.org/10.1108/JBIM-10-2012-0168

Keen P., Qureshi S. (2006) *Organizational transformation through business models: A framework for business model design*. Paper presented at the 39th Annual Hawaii International Conference on System Sciences (HICSS'06) 4–7 January 2006, Kauai, HI, USA. DOI: 10.1109/HICSS.2006.376.

Kemp S. (2019) *Digital 2019: Global internet use accelerates,* London: We Are Social. https://wearesocial.com/blog/2019/01/digital-2019-global-internet-use-accelerates, accessed 08.07.2021.

King A., Mcdermott J., Kulkarni A., Bansal N. (2020) *Reflecting and reframing: Assessing the impact of COVID-19 on strategic plans & programs and paving the path forward*, Washington, D.C.: IPSOS Global Advisor. https://www.ipsos.com/sites/default/files/ipsos-research-opportunities-for-reframing-plans-against-covid.pdf, accessed 08.07.2021.

Klimanov D., Tretyak O. (2014) Business Models: Major Research Directions and Search of Conceptual Foundations. *Russian Management Journal*, 12 (3), 107–130 (in Russian)

Klimanov D., Tretyak O. (2019) Linking business model research and marketing: New network-based approach to business model analysis. *Journal of Business and Industrial Marketing*, 34(1), 117–136. https://doi.org/10.1108/JBIM-12-2017-0330

Kushwaha T., Shankar V. (2013) Are multichannel customers really more valuable? The moderating role of product category characteristics. *Journal of Marketing*, 77(4), 67–85. https://doi.org/10.1509%2Fjm.11.0297

Leischnig A., Ivens B.S., Kammerlander N. (2017) A new conceptual lens for marketing: A configurational perspective based on the business model concept. *AMS Review*, 7(3–4), 138–153. https://doi.org/10.1007/s13162-017-0107-6

Lindgren P., Taran Y., Boer H. (2010) From single firm to network-based business model innovation. *International Journal of Entrepreneurship and Innovation Management*, 12(2), 122–137. DOI: 10.1504/IJEIM.2010.034417

Mukherjee A., McGinnis J. (2007) E-healthcare: An analysis of key themes in research. *International Journal of Pharmaceutical and Healthcare Marketing*, 1(4), 349–363. https://doi.org/10.1108/17506120710840170

Nenonen S., Storbacka K. (2010) Business model design: Conceptualizing network value co-creation. *International Journal of Quality and Service Sciences*, 2(1), 43–59. https://doi.org/10.1108/17566691011026595

Palo T., Tähtinen J. (2013) Networked business model development for emerging technology-based services. *Industrial Marketing Management*, 42(5), 773–782. https://doi.org/10.1016/j.indmarman.2013.05.015

Rangaswamy A., Van Bruggen G.H. (2005) Opportunities and challenges in multichannel marketing: An introduction to the special issue. *Journal of Interactive Marketing*, 19(2), 5–11. https://doi.org/10.1002/dir.20037

Rickwood S. (2020) *Rising to the challenge: Five key focus areas for life sciences during and after COVID-19 pandemic*, Durham, NC: IQVIA. https://www.iqvia.com/library/white-papers/rising-to-the-challenge, accessed 08.07.2021.

Robertson T.S. (2017) Business model innovation: A marketing ecosystem view. *AMS Review*, 7(3–4), 90–100. https://doi.org/10.1007/s13162-017-0101-z

Ronte H., Taylor K., Haughey J. (2018) *Medtech and internet of medical things: How connected medical devices are transforming healthcare*, London: Deloitte Centre for Health Solutions.

Rust R.T. (2020) The future of marketing. *International Journal of Research in Marketing*, 37(1), 15–26. https://doi.org/10.1016/j.ijresmar.2019.08.002

Schneider S., Spieth P. (2013) Business model innovation: Towards an integrated future research agenda. *International Journal of Innovation Management*, 17(1), 1–34. https://doi.org/10.1142/S136391961340001X

Sharma A., Mehrotra A. (2007) Choosing an optimal channel mix in multichannel environments. *Industrial Marketing Management*, 36(1), 21–28. https://doi.org/10.1016/j.indmarman.2006.06.012

Standish J., Bossi M. (2020) *How will COVID-19 change the retail consumer?*, Dublin: Accenture. https://www.accenture.com/_acnmedia/PDF-126/Accenture-COVID-19-Retail-Consumer-Resarch-Wave-Four-POV.pdf , accessed 14.06.2021.

Teece D.J. (2010) Business models, business strategy and innovation. *Long Range Planning*, 43(2–3), 172–194. https://doi.org/10.1016/j.lrp.2009.07.003

Velu C. (2016) Evolutionary or revolutionary business model innovation through coopetition? The role of dominance in network markets. *Industrial Marketing Management*, 53, 124–135. https://doi.org/10.1016/j.indmarman.2015.11.007

Yang M., Evans S., Vladimirova D., Rana P. (2017) Value uncaptured perspective for sustainable business model innovation. *Journal of Cleaner Production*, 140, 1794–1800. https://doi.org/10.1016/j.jclepro.2016.07.102

Innovation Ecosystems in the Automotive Industry between Opportunities and Limitations

Ricardo Henrique da Silva
Doctoral Candidate, Department of Mechanical Engineering[a], and Researcher, Department of Mathematics and Industrial Engineering[b], ricardohsilva@usp.br

Paulo Carlos Kaminski
Full Professor, Department of Mechanical Engineering[a], pckamins@usp.br

Rafael Ortega Marin
Consultant[c], rafaelortegamarin@gmail.com

a University of São Paulo, Butanta, São Paulo — State of São Paulo, Brazil
[b] Polytechnique Montreal, 2500 Chemin de Polytechnique, Montréal, QC H3T 1J4, Canada
[c] Gradus Management Consulting, São Paulo, Brazil

Abstract

The creation of effective innovation ecosystems (IES) at the national or sectoral level remains a difficult and not always feasible task. Basing on evidence from the Brazilian automotive industry, a case of unused opportunities for building a strong IES is considered. This is due to the insensitivity of such ecosystems to new complicated configurations and the formats of non-traditional interaction that they suggest — a "new ecology of competition", etc. The internal context of companies in relation to the practice of open innovation has been studied. Despite joint projects with close value chain partners, carmakers are showing a closed attitude to external collaboration, unlike players in industries such as aerospace or information and communications technology that gained growth and major transformation by building a broader IES. Only a high demand from the government for creating a strong IES can change the situation.

Keywords: innovation management; automotive industry; innovation ecosystem; open innovation

Citation: da Silva R.H., Kaminski P.C., Marin R.O. (2021) Innovation Ecosystems in the Automotive Industry between Opportunities and Limitations. *Foresight and STI Governance*, 15(3), 66–80. DOI: 10.17323/2500-2597.2021.3.66.80

Introduction

The automobile industry as well as other industry groups are experiencing unique moments within their life cycles. These groups evolved for several years into what is commonly referred to as an industrial innovation cluster [*Swann, Prevezer,* 1996] given that they geographically consolidated their suppliers, customers, labor, and even competitors to benefit from their scale in order to generate value for their respective stakeholders [*Baptista, Swann,* 1998; *Beaudry, Breschi,* 2003; *Bell,* 2005; *Yang et al.,* 2009; *Hering et al.,* 2011]. With the integration of developing countries into global markets, industries had to adapt again to what was called Global Value Chains [*Humphrey, Schmitz,* 2002] in order to face the increasing competitive pressure posed by new low-cost entrants [*Sturgeon, van Biesebroeck,* 2011]. However, more recently, these movements have not been enough to keep these industrial groups alive as new demands for innovation began to be imposed upon them by end users and governments. Not to mention the fact that more and more end users are increasingly considering urban cars as an expensive, complex, and unsustainable means of transportation, as one must commit a considerable part of one's personal budget for the purchase and maintenance of one's own personal vehicle [*Wright, Train,* 1987; *Prettenthaler, Steininger,* 1999; *Wu et al.,* 2015]. The total ownership cost involved is a heavy burden due to the regular maintenance involved, rapid depreciation, and other associated costs such as insurance and governmental taxes. Moreover, the current transport sector has been identified as the main contributor to greenhouse gas emissions worldwide, something that has drawn the attention of regulatory bodies around the world to draft restrictive laws [*Graham-Rowe et al.,* 2011; *Poudenx,* 2008; *Beirao, Sarsfield Cabral,* 2007]. As in other industrial sectors, such as Information and Communication Technology (ICT) [Fransman, 2010] and Aerospace [*Armellini et al.,* 2011; *Thompson et al.,* 2012], the auto industry will need to re-invent itself by understanding, and more specifically, acting as part of a wider and broader 'ecosystem' if it wants to survive all these new demands imposed on it by society.

The objective of this article is two-fold. First, the authors aim to assess whether the automotive industry is taking the first steps toward the formation of a new mobility innovation ecosystem that emerges from the changes in the industry as demonstrated in Figure 1. Second, it is to verify whether there is a positive relationship between practicing OI and the degree of innovation obtained. It is expected, from previous theory, that players that have already implemented OI practices should benefit in some way from these practices by observing, mainly, improvements in their innovation processes and/or in the degree of innovation. This will be accomplished by a questionnaire-based survey with pre-selected individuals who work for the automotive industry in Brazil in positions related to product development or innovation management.

The survey is mainly descriptive and was designed and applied to obtain insights into whether the auto sector in Brazil is pursuing Open Innovation (OI) by implementing some of its common practices. The survey also aims to assess how mature those practices are and what the main barriers are to its evolution. Previous theory already shows that OI practices are an indicator showing whether firms are preparing to open themselves to outside collaboration by integrating into a broader innovation ecosystem [*Bogers et al.,* 2017]. Brazil is an interesting country in which to conduct this research as its automotive industry produced close to 3 million units in 2019 and, besides, it has car manufacturers of Asian, European, and North American nationalities operating on its territory. This, in turn, brings their respective cultures into the routine of their operations, be it in the manufacture or in the development of their vehicles. In addition, automakers in Brazil have a variety of strategies regarding the development of their vehicle platforms, having some primary leadership in the case of small car platforms and, at the same time, having a secondary role in the development of other larger platforms. The following sections of this article will be dedicated first to presenting a review of the literature on the pattern of evolution of regional industrial clusters toward global ecosystems of collaboration and innovation. The remaining sections present the research methodology applied followed by the results of the study. Finally, a section with final remarks and directions for future research initiatives is also presented.

Theoretical Background

Moving from cluster to innovation ecosystems

The economic performance of a country is composed of the economic performance of its regions and subregions, which in turn have their performance directly linked to the presence and strength of their industry 'clusters' that operate within their geographic territory [*Lines, Monypenny,* 2018]. "Clusters are geographic concentrations of industries related by knowledge, skills, inputs, demand, and/or other linkages" [*Delgado et al.,* 2016]. When conditions are present such as a high level of technological opportunity, complex and systemic technical knowledge basis, and high "appropriability and high cumulativeness" [*Iammarino, McCann,* 2006], innovators will tend to be geographically concentrated, giving rise to emergent clusters. Even though geographically concentrated, regional industrial clusters are placed in a much broader global value chain [*Humphrey, Schmitz,* 2002]. Firms that operate in innovation clusters are more innovative and have great overall performance because they have access to a variety of intermediate inputs at a cheaper

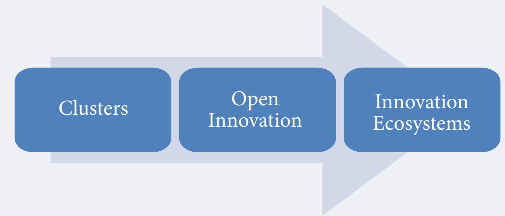
[1] http://www.anfavea.com.br/, accessed 28.11.2017.

price and also have large pools of skilled workers at their disposal [*Beadry, Swann,* 2001]. However, there are also negative aspects of operating in clusters such as increased competition arising from congestion that can undermine a cluster´s ability to growth and evolve [*Beaudry,* 2001; *Broekel, Boschma,* 2012].

When there is geographical proximity, coordination between players is enhanced by the reduced distance between them to the point where informal links begin to appear, forming a collaborative ecosystem. "(…) where constant creative feedbacks between individuals, communities and organizations occur" [*Bathelty, Cohendet,* 2014]. Studies show that engineers from industrial clusters acquire valuable knowledge through these informal networks and, at the same time, they share valuable knowledge with their informal contacts, which represents an important channel of knowledge diffusion within the cluster community [*Dahl, Pedersen,* 2004]. This temporary location proximity drives the formation of knowledge networks that increases the proximity levels between members in the long term, so that even if they are geographically apart [*Balland et al.,* 2015; *Torre,* 2008], they will keep exchanging and diffusing knowledge using tools such as business conferences, presentations, conversations, peer discussions, and observations [*Henn, Bathelt,* 2015]. This collaboration has become necessary in order to deal with the growing complexity of technologies, projects, products, and services and acts as an incentive to improve the "generation, valuation and validation of ideas" [*Koen et al.,* 2014]. It also increases the capacity of organizations to innovate, allowing the construction of connections between disciplines and industries, sectors [*Dahlander, Gann,* 2010], universities [*Walsh et al.,* 2016], and end users [*Parmentier, Mangematin,* 2014], thus forming what has been called an OI system [*Chesbrough,* 2003].

OI became a new innovation paradigm as it clearly sets the notion of a firm's 'boundaries' [*Santos, Eisenhardt,* 2005] and presents the various advantages for operating in an 'open' model versus a 'closed' model [*Gassmann, Enkel,* 2004] by making a firm´s boundaries permeable to outside-in and to inside-out knowledge flows [*Wilhelm, Dolfsma,* 2018]. Innovation and business models have since unfolded into more open and interactive arrangements [*Chesbrough, Appleyard,* 2007] in which the informal exchange of knowledge happens together with formal relationships [*Autio, Thomas,* 2014] in order to accomplish growth. "Partnerships and alignments, both downstream and upstream, became paramount for cross-fertilization and synergy" [*Traitler et al.,* 2011]. Many industrial sectors have adhered to OI strategies and practices such as the bio-pharmaceutical [*Bianchi et al.,* 2011], food [*Sarkar, Costa,* 2008], automotive [*Marin et al.,* 2018; *Ili et al.,* 2010], chemical [*Sieg et al.,* 2010], and ICT [*Bigliardi et al.,* 2012] among others. As firms learn, mature, and adapt to OI practices in general, the next step is to organize themselves into a broader and more diverse

Figure 1. **Evolution toward the Formation of an Innovation Ecosystem**



Source: authors.

group of actors throughout the various stages of their innovation process [*Bogers et al.,* 2017], evolving into what has been called more recently 'innovation ecosystems' [*Rohrbeck et al.,* 2009], or, depending on the perspective, 'business ecosystems' [*Gomes et al.,* 2018]. Such has been the case of important sectors such as the ICT [*Fransman,* 2010] and aerospace [*Thompson et al.,* 2012] innovation ecosystems.

Innovation ecosystems are a natural step for firms that initiated and adopted OI practices [*Torre, Zimmermann,* 2015]. Innovations in a networked industry environment, in general, are not the object of a single invention, but are the result of new products that are developed, new processes that are assembled, and even of new technologies, all brought together by a large variety of participants [*Iansiti, Levien,* 2002]. As soon as firms learn to cooperate and collaborate with outside actors and they start to see the innovation results from that collaboration, the next step is for them to move into a broader "industrial ecology system" [*Torre, Zimmermann,* 2015] or into a "new ecology of competition" [*Moore,* 1993]. Innovation ecosystems cross a variety of industries in which firms evolve their capabilities around any given innovation [*Moore,* 1993]. It might also be described as "the collaborative arrangements through which firms combine their individual offerings into a coherent, customer-facing solution" [*Adner,* 2006]. Complex innovations tend to involve a series of actors demanding changes and are not confined to their supply networks [*Adner, Kapoor,* 2010] as they also include other participants such as end users, governmental agencies, universities, and other coordinators or intermediaries that co-evolve within a "symbiotic relationship" [*Iansiti, Levien,* 2004]. Innovation ecosystems promote the interaction of innovation networks and knowledge clusters formally and informally, what "(…) catalyzes creativity, triggers invention and accelerates innovation across scientific and technological disciplines, public and private sectors" [*Carayannis, Campbell,* 2009].

The new mobility innovation ecosystem

Innovation ecosystems are the result of an evolutionary process and there is no single recipe that explains how innovation ecosystems emerge or are created as multiple formats emerge in the literature [*Rabelo, Bernus,* 2015], however they can be classified according to their maturity level [*Moore,* 1993], the roles and the dynamics present in the relationship between their participants [*Kapoor, Lee,* 2013] and, also, according to the platform [*Gawer, Cusumano,* 2014] or the value that is co-created [*Benitez et al.,* 2020].

In the case of the auto industry, the new ecosystem it joins should go beyond current and traditional partners and be based on a wide range of actors and efforts. Many call this new innovation ecosystem Smart Mobility [*Pulkkinen et al.,* 2019; *Karim,* 2017] as it involves efforts produced by a chain of actors that use intelligent sharing systems to provide end-to-end mobility [*Ning et al.,* 2017]. Moreover it can go further and be called a Sustainable Mobility Ecosystem [*Ma et al.,* 2018; *Lyons,* 2018] if, in addition, it prioritizes the use of low-carbon modes of transport and covers governments and regulatory entities [*Banister,* 2007]. This new ecosystem also embraces the current auto industry and all the technological changes that are occurring within its products, such as the introduction of engines powered by renewable energy [*Rajashekara,* 2013] and ICT technologies that are allowing automotive vehicles to become increasingly autonomous [*Burns,* 2013]. It also embraces a multitude of start-ups and new business models [*Bellini et al.,* 2019] that are emerging and turning the vehicle into something shared and connected with other transport hubs that provide mass and micro mobility [*Jittrapirom et al.,* 2017; *Chong et al.,* 2011; *Ho et al.,* 2018; *Smith et al.,* 2018].

The size and coverage of the Mobility Innovation Ecosystem is also important to understand as are some basic practices that can take the current auto industry into a more innovative state. It is also critical to grasp how open the current industry is to these practices. Certainly, there are some intermediate steps before operating in a 'ecosystemic' mode. Several publications point to digitalization and OI as the background or even a necessary step on the path toward innovation strategies in a platform-based ecosystem [*Bogers et al.,* 2017; *Oberg, Alexander,* 2019; *West, Bogers,* 2014; *West et al.,* 2014]. These publications propose a positive correlation between OI practices and the formation and subsequent consolidation of an ecosystem afterwards. When firms start to practice OI, they open themselves to various kinds of interactions and knowledge flows between different types of development as well as commercialization players, even before a value creating ecosystem architecture is established. That movement is reinforced if the ecosystem being formed is platform-based, i.e., uses common standards to integrate products, services, and firms. This is a practice already known by the auto industry and has been used among its Tier 1 suppliers to develop its current products [*Teece,* 2018] for a long time already.

Research Methodology

The objective of this research is mainly descriptive because it seeks mainly to portray the collaboration pattern of a specific industry sector (the automotive industry) in a specific territory (Brazil), based on what has already been established in previous theory. The research methodology chosen by the authors involves collecting data from primary sources using a questionnaire-based survey [*Forza,* 2002] followed by the analysis of the data using a statistical software, such as Stata[2] for example, in order to deploy descriptive statistical analysis as well as a regression analysis. The sampling process used was non-probabilistic and was done per convenience due to the qualitative nature of the research. The questionnaire-based survey was designed to assess the interviewees' knowledge and experience and the common practices around OI at their respective companies. Since the 'Innovation Ecosystem' is a concept not completely understood within the auto sector yet, OI was the theme chosen to be surveyed as a proxy.

Brazil was the territory chosen to be surveyed mainly due to its heterogeneous automotive industry and the fact that it is capable of reflecting the corporate culture of the main automakers in the world. Although there is no genuinely Brazilian vehicle manufacturer on the international stage, the country is home to important automakers from Europe, Asia, and North America that have R&D and manufacturing operations on Brazilian territory and, consequently, end up reflecting the culture and strategies of their headquarters located abroad. In addition, the automobile sector is an important engine of the Brazilian economy (see Table 1), representing 18% of its industrial GDP, being the 6th largest domestic market, and the 8th largest worldwide producer[3], despite the economic crisis that hit the sector in 2014.

Survey design

The research questions were developed over a timeframe of approximately six months and included two interviews that were made with OI researchers to discuss the theoretical bases that supported the questionnaire, and another two interviews with innovation specialists from the automotive industry to evaluate and suggest improvements to the questionnaire. After this stage, the survey was tested on a small group of five industry respondents for fine adjustments. After completing this process, the survey was sent to the sample of professionals that were selected using an existing database of experts from one of the most renowned automotive graduate continuous education courses in Brazil. The survey was designed and applied to extract information about three major constructs related to OI that have already been explored in previous literature

[2] Stata is a general-purpose statistical software package that belongs to StataCorp.

[3] http://www.anfavea.com.br/, accessed 28.11.2017.

Table 1. **Brazilian Automotive Industry Overview in 2019**

Companies		Factories	
Automaker Brands	26	Industrial Units	65
Autoparts	473	States	10
Dealers	5.249	Passenger automaker nationalities	8
State name	**List of passenger car manufacturers in operation**		
Bahia	Ford		
Ceará	Ford (Troller)		
Goiás	Hyundai, Suzuki, Mitsubishi		
Minas Gerais	FCA, Mercedes-Benz		
Paraná	Audi, Nissan, Renault, VW		
Pernambuco	FCA		
Rio de Janeiro	Nissan, Land Rover, PSA		
Rio Grande do Sul	GM		
Santa Catarina	BMW		
São Paulo	Chery, Ford, GM, Honda, Hyundai, Toyota, VW		

Source: [ANFAVEA, 2020].

Table 2. **Survey Structure**

Construct	Variable	Theoretical Basis	Scale	Questions
OI Organizational Culture	• Most important partnerships • Reasons for partnership • Cultural Aspects	[*Wilhelm, Dolfsma,* 2018; *Ili et al.,* 2010; *Mortara, Minshall,* 2011; *Lewin et al.,* 2017; *Breunig et al.,* 2014]	• Likert (1–5) • Likert (1-6) • Likert (1-5)	• F1-F4 • B1, B2, B6 • B4, B5, B7, D3
PDP Aspects	• Degree of innovation • Adoption of newer PDP methods	[*Cooper,* 2015]	Likert (1–6)	• C1 • C2
OI Barriers & Risks	• Perceived barriers and risks	[*Ili et al.,* 2010; *Aquilani et al.,* 2017; *Monteiro et al.,* 2017]	Likert (1–5)	• D4

Source: authors.

as demonstrated in Table 2. Each construct was then broken down into measures and each measure was divided into questions or blocks of questions in the survey. Finally, each question was treated as a single variable during the statistical analyses carried out with the Stata software. In Table 2, the three main constructs and their respective measures are presented, together with the theoretical basis used to design the questions.

In the first construct, 'OI Organizational Culture', the object was to list the main actors or partners involved in the practice of OI at the firm [*Wilhelm, Dolfsma,* 2018; *Ili et al.,* 2010], as well as the main activities carried out through this partnership in addition to the reasons that motivated such association [*Mortara, Minshall,* 2011; *Lewin et al.,* 2017]. Cultural aspects of the firm in relation to the practice of OI was also explored with the main objective of verifying whether there has been an increase in the practice of OI in recent years or not [*Breunig et al.,* 2014].

The 'OI Barriers and Risks' construct encompasses all issues that address factors that hinder or block the implementation of OI projects by the firm [*Ili et al.,* 2010]. Internal and external risks are addressed. In the case of internal risks for an organization, it is possible to list a corporate culture that does not favor OI, the opposition or even passivity of employees in addition to the lack of resources or investment [*Aquilani et al.,* 2017]. As for external risks, they can include a lack of trust from partners, the possibility of theft or misappropriation of important information or technologies, or even the loss of control of projects that are being conducted in partnerships [*Monteiro et al.,* 2017].

With regard to the 'Product Development Process (PDP)' construct, the main questions try to assess the degree of innovation carried out by the firm (if radical or incremental) in recent years as well as whether the organization has managed to evolve in its PDP process by adopting new practices such as Agile[4] methodologies or rapid prototyping techniques for example [*Cooper,* 2015].

The main demographic variables measured were 'company' and 'plant/unit' size (A1), 'age of respondents' (G3), 'respondent area of expertise' (G2), and the respondent's 'job title' (G1 and G4).

Survey application

The prepared research was applied to directors, managers, and engineers who were working in innovation-related departments in the auto industry such as product and project development areas (product engineering, application, and systems engineering) at the time of the research. Other criteria, such as having enrolled in a graduate course or publishing an article in a journal or for a scientific event, were also used to find potential interviewees. In total, 1,032 invitations were sent, of which 342 started the survey. Of this, 140 individual responses were obtained with valid information for statistical treatment, comprising a response level of 13.6%. This low response rate was not considered a cause of non-response bias as the survey was mainly

[4] The project management methodology that uses short development cycles is also called 'sprint.'

exploratory and, at the same time, had an average response time of approximately 40 minutes, considered relatively high for these types of questionnaire-based surveys [*Forza,* 2002], which certainly could decrease the response rate.

The survey was sent by e-mail and responses were collected electronically throughout the second half of 2018, with two follow-up phone calls, the first to ensure that people received the questionnaire and, later, the second to remind respondents about the due date. An effort was made for all major automakers with R&D operations in Brazil to receive the survey. The same effort was made to include a diverse range of suppliers, covering major automaker´s auto parts. With only a few exceptions, most questions used a 5-point or 6-point Likert scale, as shown in Table 2, to measure the importance of each research variable according to the experience and/or perception of the respondent in relation to the behavior of their own company.

Sample Characterization

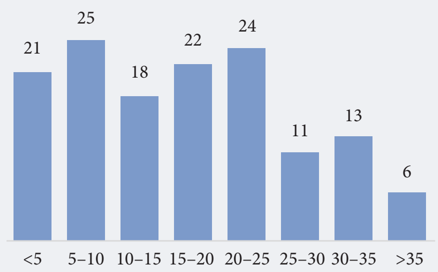
The first variable evaluated was the level of experience of the interviewees in relation to their working time in the automotive industry. Respondents had an average of 16 years of experience in the sector.The distribution is shown in Figure 2.

Overall, the seniority level of the surveyed sample was considered moderate to high, which is considered a positive aspect given the particularities of the automotive industry and the fact that obtaining answers from knowledgeable interviewees about the industry reduces random and bias error [*Forza,* 2002]. In addition, most respondents answered that their companies have a high concentration of their revenue coming from the automotive sector, as per Figure 4, and with considerable Research and Development (R&D) units located in Brazil by the time the survey was done, as demonstrated by Figure 3.

As is shown in Figure 5, the sample of interviewees was evenly distributed between automakers and suppliers, so that close to 50% of respondents came from automotive manufactures and the other 50% was split between auto parts, assembled sub-system suppliers, and service providers. Another important piece of information about the sample is that around half of the respondents came from companies with at least 1,000 employees working full-time at the time of the survey. Between 25% and 30% respondents came from companies with between 100 and 1,000 full-time employees, which shows the predominance of large and medium-sized companies, as shown in Figure 6.

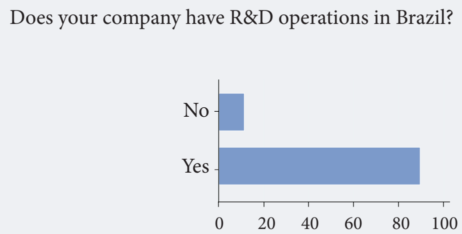
It is worth mentioning that the survey was carried out in 2018 but reflects information from 2015 through 2017, years during which the automotive industry in Brazil was still recovering from a serious economic crisis that hit Brazil and the whole auto sector in 2014 with a 13.6% drop in light vehicle production in that year alone [*Amorim,* 2014]. Figure 8 shows that the

Figure 2. **Experience in the Automotive Industry (years)**



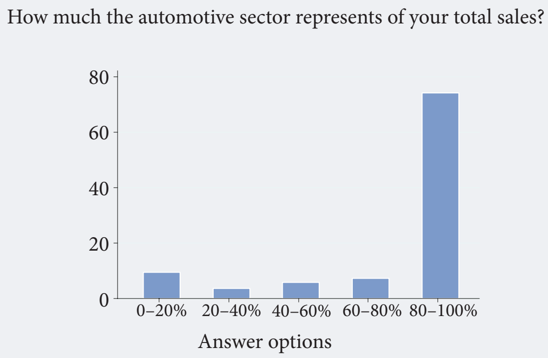
Source: authors.

Figure 3. **R&D Operations in Brazil (shares of responses, %)**



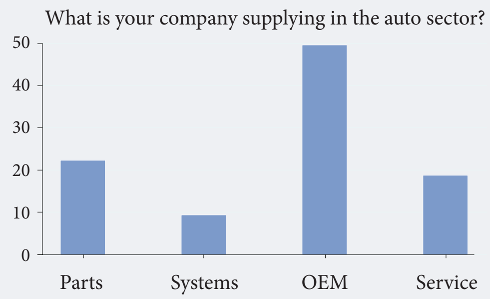
Source: authors.

Figure 4. **Business Concentration (shares of responses, %)**



Source: authors.

Figure 5. **Position in the Supply Chain (shares of responses, %)**



Source: authors.

companies of the majority of respondents had a significant reduction in the number of active customers in the years prior to the time of the survey. Figure 7 also shows that the majority of companies interviewed also experienced a significant reduction in their revenue streams.

Descriptive Analysis of the Main Research Constructs

'OI organizational culture'

After the sample characterization, the first construct to be analyzed was the 'OI organizational culture'. In this construct, the survey tries to identify the existence of OI practices among the companies that were analyzed and the maturity and importance of these practices for overall corporate strategy. As described in Figure 9, nearly 80% of respondents stated that their companies knew and had OI practices in place for at least two years. Close to 45% had these practices in place for more than five years and more than 30% had them for more than 10 years. Under 5% stated that OI practices had ceased being used at their companies.

With regard to the perception of the maturity of OI practices, the survey results showed, as demonstrated in Figure 10, that close to 30% of the interviewees said OI was an 'essential' part of their innovation process, with targets, tools, and methods well established and aligned with the strategic plan of their companies. Another 30% said it was in the 'development stage' meaning it was being actively promoted within their companies but not yet truly consolidated. However, near 40% stated that the OI was still in the introductory phase with only a few experiments, but not yet formally incorporated into the innovation process.

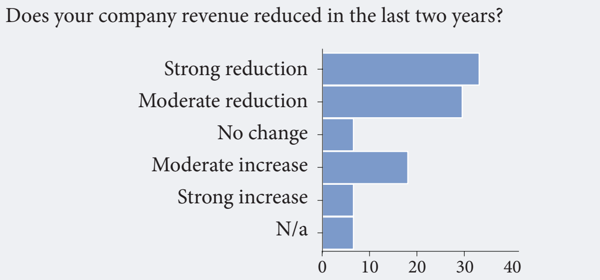
Also, an important variable measured within this survey was the importance that OI had within the strategic innovation plan of the companies that responded to the survey. As shown in Figure 11, for both automakers and suppliers, OI practices were considered important or very important to their company's innovation strategies for nearly 70% of the respondents. An interesting point of the research is that, counterintuitively, there was a small advantage for suppliers in relation to the degree of importance that OI practices had when compared to automakers, as demonstrated in Figure 11.

Another important observation that can be drawn from the results of this survey, is to determine in which innovation paradigm the Brazilian automotive industry fits best. According to [*Chesbrough*, 2003] there are two possible paradigms: 'Open Innovation' versus 'Closed Innovation'. To determine the status of a company or industry sector in relation to these paradigms, an analysis should be performed on six different criteria: attitude regarding research, field of expertise, function of one's own R&D, intellectual property, market ambition, and sources for ideas. From the survey's results, presented in Figure 12, it becomes clear that

Figure 6. **Number of Full-time Employees (shares of responses, %)**

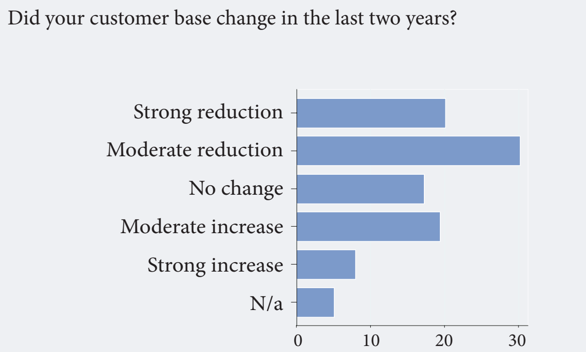
Source: authors.

Figure 7. **Revenues Reduction (shares of responses, %)**



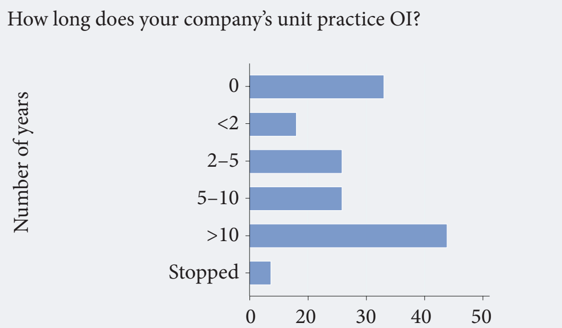
Source: authors.

Figure 8. **Customer Reduction (shares of responses, %)**



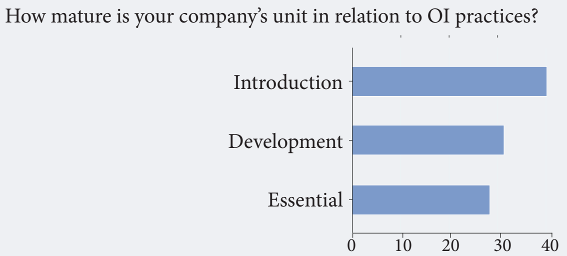
Source: authors.

Figure 9. **OI Practice Longevity (shares of responses, %)**



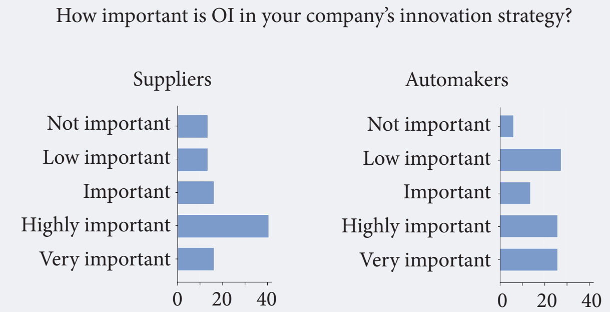
Source: authors.

Figure 10. **Perception of OI Maturity (shares of responses, %)**



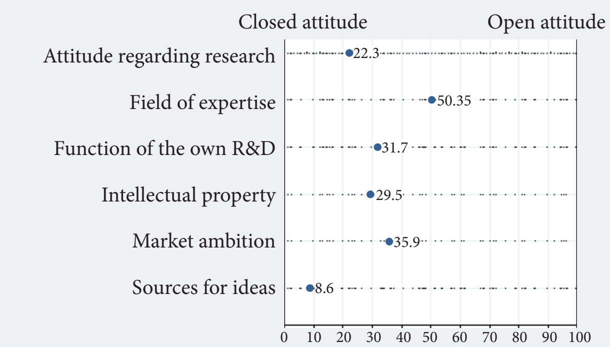
Source: authors.

Figure 11. **Importance of OI in Innovation Strategies (shares of responses, %)**



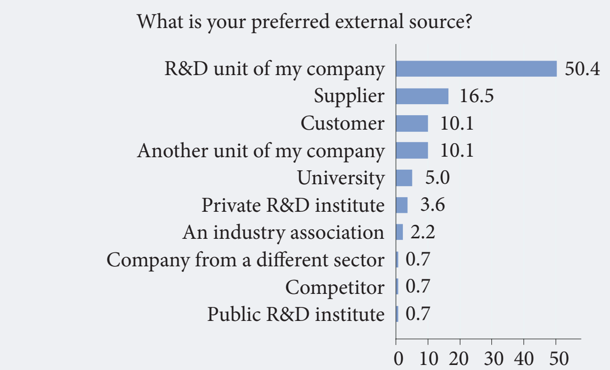
Source: authors.

Figure 12. **Contrasting Principles of Closed and Open Innovation (shares of responses, %)**



Source: authors.

Figure 13. **External Sources for Collaboration (shares of responses, %)**



Source: authors.

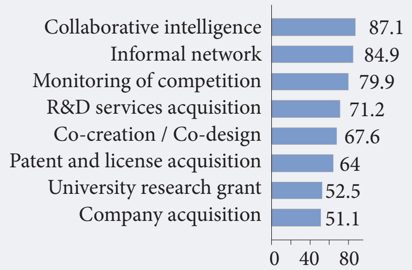
the auto industry in Brazil has difficulties in opening and collaborating, given the tendency of the interviewees toward the closed innovation paradigm. A similar analysis was performed by Albers and Miller (2010) on the German auto industry [*Albers, Miller,* 2010] with analogous results.

As for the preferred external sources used by the automotive industry in Brazil, as depicted in Figure 13, it becomes evident that there is also a preference expressed by respondents for using other R&D units of the same company as well as direct suppliers or customers as possible partners for collaboration when starting new projects. Public R&D institutes and competitors are rarely cited by the interviewees. Universities are cited by only 5% of the respondents, also showing low integration and collaboration between the private and public sectors.

As for preferred 'outside-in' initiatives, according to Figure 14, most respondents answered that their companies used internal collaborative intelligence tools to capture information from beyond the frontiers of their respective companies (external environment). This would include benchmarking in multi-functional teams to interpret the market and suggest new products, for example. Informal networks also rank high, which is in line with previous literature that already shows these types of linkages to be common, mainly among people that work in geographic proximity, for example, in the same regional industry cluster [*Dahl, Pedersen,* 2004].

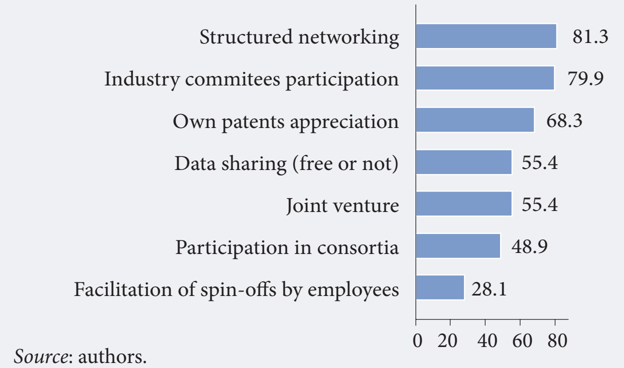
Also, in Figure 14, the acquisition of R&D services and co-design/co-engineering were reasonably cited. This type of initiative is very common among customer-supplier partnerships or vice-versa, something that happens within the automotive industry when a vehicle manufacturer establishes a partnership with a supplier of combustion engines for the specific development of a new engine, for example. Once again, research grants for universities appear at the bottom of the graph showing that companies are less interested in this type of initiative as well as the acquisition of new companies. Monitoring the competition is the third most cited outside-in initiative as most automo-

Figure 14. **Main Outside-In Initiatives (shares of responses, %)**



Source: authors.

Figure 15. **Main Inside-Out Initiatives (shares of responses, %)**



Source: authors.

tive companies have their own programs to check on the performance of their competitor´s products, such as the 'tear-down' initiative very common among automakers in which they acquire competitors' vehicles on the market, bring them to their engineering labs and then dismantle the cars to check components and technological features in order to improve their own products or establish some advantage. After analyzing the results of this section of the research, it is also clear that, although there are many initiatives from the inside out, they are uncoordinated and do not show a clear path that goes out from within company boundaries, leading to the external environment, outside the borders of the company.

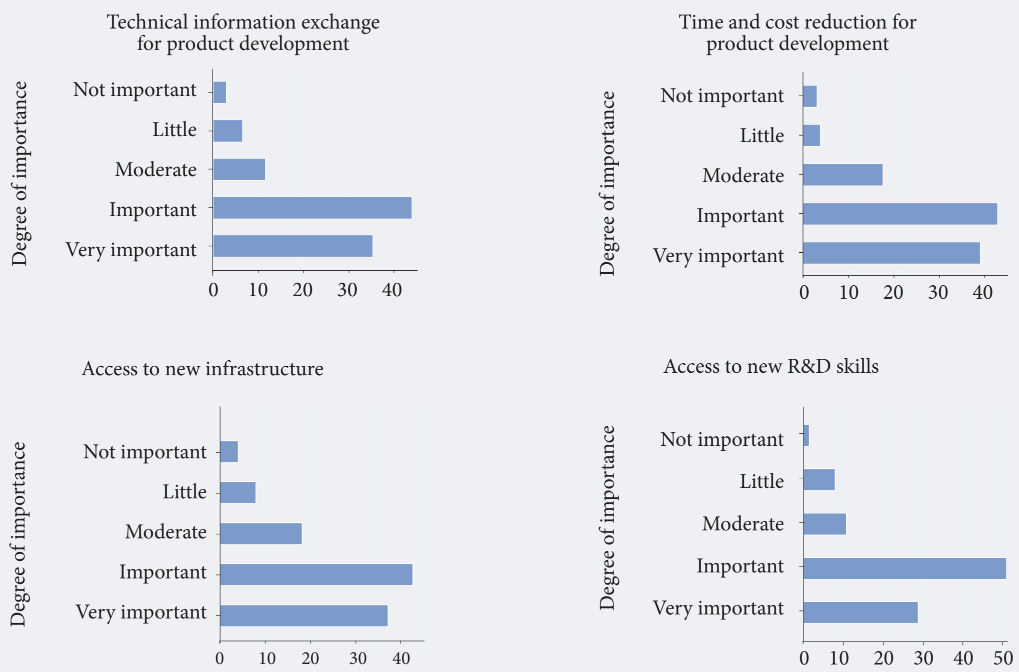
As for the preferred 'inside out' initiatives, according to Figure 15, most respondents pointed to the structured network as the main initiative, along with participation on industry committees for standardization. The structured network usually involves sharing knowledge at industry meetings, forums, on social media, and at congresses. Standardization committees are more concerned with creating best practices and the normalization of the sector´s practices. Those are, once again, typical inside-out initiatives from industries or companies that still have a closed mindset. There is not yet an active mindset for exploiting their own discoveries and spin-offs. Such initiatives were rarely mentioned among respondents, which, again, shows that there is still a strong tendency to keep everything inside companies.

In general, the initiatives that are highlighted in this part of the research, in Figure 13, Figure 14, and Figure 15, point to an environment known as 'me-too-innovation' [*Ili et al.,* 2010], i.e., they do not lead companies and industries to innovations considered more radical or disruptive, staying too much in the 'same old same old' incremental process of improving their own existing products. This is a scenario in which limited collaboration prevails and where industrial clusters are unable to evolve into a broader ecosystem of innovation.

'PDP aspects'

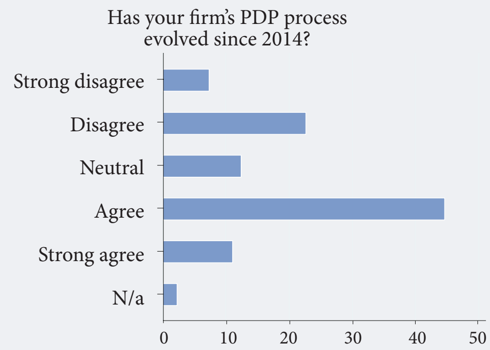
When it comes to PDP, the research yielded two relevant contributions. The first relevant contribution is the fact that it shows that 'PDP improvements' are one of the major reasons for companies in the auto sector to establish partnerships, even if, as already demonstrated, this is done within their close circle of partners, such as customers and direct suppliers. When the in-

Figure 16. **Main Reasons Why Companies Collaborate (shares of responses, %)**



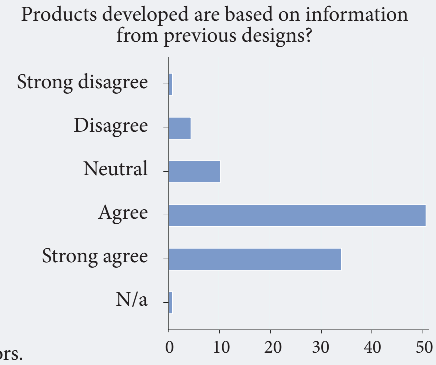
Source: authors.

Figure 17. **PDP Evolution (shares of responses, %)**



Source: authors.

Figure 18. **Type of PDP Projects (shares of responses, %)**



Source: authors.

terviewees are asked about the main reasons that motivated their partnerships, the answers with the greatest statistical representation were, according to what is presented in Figure 16: (1) obtain or exchange technical knowledge, (2) access to infrastructure (laboratories and equipment for example), (3) access to new R&D processes and, lastly, (4) the reduction of the time and cost for the development of new products.

The second relevant contribution is that, even though the interviewees responded that the PDPs of their companies have evolved since 2014 (as shown in Figure 17), the products developed by these processes have not changed significantly, i.e., the PDPs still largely focus on the development of incremental products as shown in Figure 18.

'OI barriers and risks'

When asked about the reasons or reasons why OI did not progress within their respective companies, there were several reasons cited by the respondents as shown in Figure 19.

Figure 19. **Main Barriers that Hinder OI (shares of responses, %)**

Source: authors.

In general, all the reasons were very well scored by the respondents, with special emphasis on the reason "Lack of Clarity in the OI strategy". In the sequence, other motivations appear strongly connected with ignorance concerning how OI works and a lack of clarity about management's discourse. There is still a latent fear within organizations to open and lose control of projects that are done in partnerships or even a lack of trust in their partners. Finally, there is still the passivity on the part of employees who, in a way, do not pull the initiatives forward by demanding and asking for them to become mainstream within their companies. All these reasons make the lack of a clear strategy for OI evident within the interviewed companies and, in a way, portrays the situation of the automotive sector in Brazil and, possibly, elsewhere.

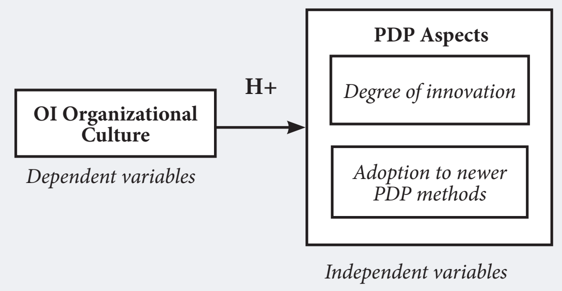
Regression Analysis for OI Practices

To confirm reliability of the research, a statistical regression was performed to verify whether, within the selected sample of respondents, the hypothesis that companies that have a culture that favors the practice of OI perceive a positive effect on their innovation results, which in this research directly translates into improvements in the PDP construct. The practice of OI and its positive impact upon the companies' PDP process, whether improving the current process or leveraging innovations, is something widely explored and consolidated in the literature and therefore, should be confirmed by the results of the statistical regression analysis of the conceptual model in Figure 20 to bring reliability to the survey results.

These hypotheses are then tested using a measure-by-measure analysis. The complete set of hypotheses are summarized in the Table 3.

The measures presented in Table 3 were subjected to rotated principal-component factor (PCF) analyses to reduce and identify the relevant factors for each measure. Orthogonal rotations (varimax) were performed using Stata/IC13 software. The criteria chosen for adopting or discarding factors was based on a mini-

Figure 20. **Conceptual Model**



Source: authors.

Table 3. **Hypotheses for the Regression Model**

Hypothesis	Dependent measure	Independent measure
H1	• Cultural aspects (regarding OI practices) • Survey questions: B4, B5, B7 and D3 • Question's scale: Likert 1-5	Degree of innovation (incremental/radical) • Survey question: C1 • Question's scale: Likert 1-5
H2		Adoption to newer PDP methods/models • Survey question: C2 • Question's scale: Likert 1-5

Source: authors.

mum eigenvalue of 1.0, with a minimum Cronbach's alpha of 0.6. Variables with a factor loading of less than 0.5 were purged and the analysis was iteratively rerun. A Kaiser-Meyer-Olkin (KMO) test was also used to assess the sampling adequacy for each measure in the model, with a minimum threshold of 0.5.

Organizational culture was assessed by asking respondents, on the same scale, to assess characteristics of management and employees that can improve the adoption of open innovation systems (i.e., the company has an environment that favors open innovation practices). For this group of questions (Table 4), two factors with an eigenvalue greater than 1 were found. The first factor, 'Cult_Aspects_F1' (= 3.55), explains 39% of the variance with a Cronbach-alpha of 0.87. The second factor, 'Cult_Aspects_F2' (λ = 2.58) explains 29% of the variance with an alpha of 0.80. Both factors are kept in the analysis.

Two additional variables, 'OI_Maturity' and 'OI_Strategy', assessed the respondents' perception of how mature the company is with regard to open innovation practices and how integrated into its strategy open innovation is, respectively. Since each of these variables correspond to a single question in the survey, they are kept as distinct variables.

For the construct PDP Aspects, both questions use a five-point Likert scale (from completely disagree to completely agree). The first asks respondents to assess how incremental or radical the innovations performed by their company are, the second measure assesses whether the processes related to product development have changed in the last few years (since 2014) and whether new methods and tools have been adopted.

For the degree of innovation measure (Table 5), two factors with an eigenvalue greater than 1.0 were found. 'PDP_Degree_F1' (λ = 1.51) presented a Cronbach-alpha of 0.67 and remained in the analysis. Even though the other factor presented a sufficient eigenvalue, its Cronbach-alpha was 0.58 and was discarded from the analysis.

Table 4. **Organizational Culture in OI Factor Analysis**

Degree of innovation performed in their company	Factor 1 (PDP_adoption)	λ Factor 2 (discarded)
Management encourages teamwork	0.89	-
Management encourages everyone's participation in the search for solutions	0.87	-
Leaders or managers in your plant/unit have the flexibility needed to implement changes	0.57	-
Employees' suggestions for improvement are encouraged	0.73	-
Employees that propose improvements are recognized for their solutions	0.61	-
The company offers training to its employees	0.68	-
The company uses techniques to stimulate creativity among its employees	-	0.69
A team (dedicated or not) is in charge of promoting a culture of open innovation within the more general corporate culture	-	0.81
Indicators specific to open innovation are used	-	0.88
% prop.	0.39	0.29
% cumul.	0.39	0.68
Eigenvalue	3.55	2.58
Cronbach-alpha	0.87	0.80
KMO	0.81	

Source: authors.

Table 5. **Degree of Innovation Performed in their Company Factor Analysis**

Degree of innovation performed in their company	Factor 1 (PDP_ adoption)	Factor 2 (discarded)
The products developed are more incremental than radical in their innovations	0.86	-
The products are developed based on information from prior projects / products	0.87	-
Products are being developed to new target markets	-	0.84
The products developed necessitated the development of a new platform and / or new business models	-	0.83
% prop.	0.38	0.36
% cumul.	0.38	0.73
Eigenvalue	1.51	1.42
Cronbach-alpha	0.67	**0.58**
KMO	0.59	

Source: authors.

Table 6. **Adoption of Newer PDP Methods and Tools**

Adoption to newer PDP methods and tools	Factor 1 (PDP_ adoption)
The way PDP is done has changed since 2014	0.70
Open innovation has influenced the way PDP is done	0.94
Open innovation is responsible for the improvement of existing and implemented PDPmethods or tools in your plant / unit	0.96
Open innovation is responsible for the adoption of new PDP methods or tools (scrum, agile, etc.) in your plant / unit	0.91
% prop.	0.78
% cumul.	0.78
Eigenvalue	3.12
Cronbach-alpha	0.90
KMO	0.80

Source: authors.

Table 7. **OLS Regression Correlations for H1 & H2: OI Organizational Culture versus PDP Aspects**

Measure	Dependent Variable	Independent Variable	
		PDP_ Degree	PDP_ Adoption
Cultural aspects	Cult_Aspects_F1	0.11	**0.35*****
	Cult_Aspects_F2	–0.06	**0.35*****
	OI_Strategy	0.13	**0.60*****
	OI_Maturity	**0.21***	0.19*

Note: p-values: + p<0.1, * p<0.05, ** p<0.01, *** p<0.001 (highlighted in bold).

Source: authors.

Table 8. **Hypothesis Test Results**

Hypothesis	Independent measure	Hypothesis test results
H1	• Degree of innovation (incremental / radical)	Partially Accepted
H2	• Adoption to newer PDP methods/models	Accepted

Note: Dependent variable — Cultural aspects (regarding OI practices).

Source: authors.

Finally, for the measure of adoption of newer PDP methods and tools (Table 6), only one factor remained, 'PDP_adoption' (λ = 3.12), explaining 78% of the variance found. With a Cronbach-alpha of 0.9 and KMO of 0.8, it was kept in the analysis.

Regression analysis

After a correlation matrix was performed with the variables created for the regression and no significant correlation was observed between the same group of measures, the next step was to move on to the regression. Ordinary Least Squares (OLS) regressions were performed using Stata/IC13 software. All variables created were considered in the analysis as well as the respondent's origin (as in, from an automaker or supplier) is used as a control variable. Variables in the regression that resulted in a significant p-value, which is taken to be less than 0.1 in this exploratory analysis, are highlighted in bold in Table 7.

The results of the hypothesis testing from the conceptual model presented in Figure 19 is found in Table 8.

Hypotheses H1 and H2 concern the measure of 'Cultural Aspects' to the 'Degree of Innovation' and 'Adoption of newer PDP methods', respectively. The cultural aspects measure asks respondents to assess changes in open innovation culture that their company might have experienced in the past few years, as well as asking respondents to assess characteristics of management and employees that can improve the adoption of open innovation engagements (i.e. the company has an environment that favors open innovation practices).The results suggest a positive relationship between having a corporate culture that favors open innovation practices and evolving their PDP to adopt newer methodologies, as well as having a greater focus on radical innovation, which confirms the previous theory about OI and, thus, brings reliability to our study.

Conclusion

This is descriptive research that aims to show evidence that the automotive industry in Brazil does not display a collaboration pattern typical of an innovation ecosystem that usually involves a wide range of actors such as competitors, government agencies, universities, private and public research entities, among others. This has been accomplished by conducting a questionnaire-based survey to gain insights into the three main constructs that are widely discussed in the literature about OI and ecosystems of innovation and can serve as indicators to show whether a particular company or industrial sector is entering a broader ecosystem of collaboration or not. The first construct is the organizational culture around OI and, observing the research results, although the automotive industry in Brazil knows and values OI and has implemented some of its practices, it still has a 'closed attitude', because it relies heavily on its own resources, such as R&D, to develop new products, new technologies, and explore new ideas. Besides, the survey results showed that most of the new partnerships implemented are between close partners, such as direct suppliers and customers, and have not yet extended to more distant actors, such as competitors, universities and other public and or private research agencies. Also, the initiatives are still very much focused on the 'outside-in' direction, based essentially on collaborative intelligence and informal networking. As for IP, research has shown that it has not yet been properly explored in both, the 'inside-out' and the 'outside-in', directions.

Another important contribution brought by this research is the fact that it shows that the main reason why participants in the automotive industry establish new partnerships is to improve their PDP, whether by providing access to new technical information/skills or by providing access to new R&D infrastructures. In addition, research has shown that while the PDPs have improved over time, new products developed by these processes are still primarily of an incremental nature. As for the main barriers that prevent OI from progressing and evolving, the results of the research show that, in most cases, the main roadblocks are usually related to a lack of clarity in the OI implementation strategy, inadequate tools/resources or a lack of knowledge about the proper use of tools/resources, a gap between the company culture and the culture of OI, among others. The results point to the existence of a latent fear in organizations to open and lose control of projects carried out as part of partnerships or even a lack of trust in their partners when working in collaboration agreements.

Finally, a regression analysis was conducted to confirm the hypothesis that companies that have a more collaborative attitude (by practicing OI for example) obtain better results in their PDPs, either through the evolution of the methods that are used or by improving the level of innovation of the products that are developed. The results obtained through the regression test demonstrated a positive effect of this relationship, confirming the previous existing theory and giving validity to this research.

The results of this research demonstrate the need for public authorities and private entities to act together in the formulation of public policies to support historical and traditional actors in their process of evolution and integration into an innovation ecosystem whether they are still in a nascent or emerging phase. If no adaptation or strategy change is adopted by such players and no public support policy implemented, there is a risk that these large players will not be able to penetrate the entry barrier of these innovation ecosystems, losing the leadership of their markets, and becoming only marginal players, if they do not collapse before.

The authors thank the Automotive Engineering Center (AEC) of the Escola Politécnica (Engineering School) of the University of São Paulo (Poli-USP) for the support provided to develop and apply the questionnaire-based survey to the automotive industry in Brazil.

References

Adner R. (2006) Match your innovation strategy to your innovation ecosystem. *Harvard Business Review*, April. https://hbr.org/2006/04/match-your-innovation-strategy-to-your-innovation-ecosystem, accessed 18.02.2021.

Adner R., Kapoor R. (2010) Value creation in innovation ecosystems: How the structure of technological interdependence affects firm performance in new technology generations. *Strategic Management Journal,* 31 (3), 306–333, https://doi.org/10.1002/smj.821

Aquilani B., Abbate T., Codini A. (2017) Overcoming cultural barriers in open innovation processes through intermediaries: A theoretical framework. *Knowledge Management Research and Practice*, 15(3), 447–459. https://doi.org/10.1057/s41275-017-0067-5

Armellini F., Kaminski P.C., Beaudry C. (2011) Consortium for research and innovation in aerospace in Quebec, Canada a reference model for the Brazilian aerospace industry. *Product Management & Development*, 9(2), 101–109. DOI: 10.4322/pmd.2012.002.

Autio E., Thomas L.D.W. (2014) Innovation ecosystems: Implications for innovation management. In: *Oxford Handbook of Innovation Management* (eds. M. Dodgson, D.M. Gann, N. Phillips), Oxford: Oxford University Press, pp. 204–228. DOI: 10.1093/oxfordhb/9780199694945.013.012.

Balland P.A., Boschma R., Frenken K. (2015) Proximity and Innovation: From Statics to Dynamics. *Regional Studies*, 49(6), 907–920. https://doi.org/10.1080/00343404.2014.883598

Banister D. (2007) Cities, mobility and climate change. *Journal of Industrial Ecology*, 11(2), 7–10. https://doi.org/10.1162/jie.2007.1271
Baptista R., Swann P. (1998) Do firms in clusters innovate more? *Research Policy*, 27(5), 525–540. https://doi.org/10.1016/S0048-7333(98)00065-1
Bathelty H., Cohendet P. (2014) The creation of knowledge: Local building, global accessing and economic development-toward an agenda. *Journal of Economic Geography*, 14(5), 1–14. https://doi.org/10.1093/jeg/lbu027
Beadry C., Swann P. (2001) *Growth in Industrial Clusters: A Bird's Eye View of the United Kingdom*, Stanford, CA: Stanford Institute for Economic Policy Research.
Beaudry C. (2001) Entry, growth and patenting in industrial clusters: A study of the aerospace industry in the UK. *International Journal of the Economics of Business*, 8(3), 405–436. https://doi.org/10.1080/13571510110079000
Beaudry C., Breschi S. (2003) Are firms in clusters really more innovative? *Economics of Innovation and New Technology*, 12(4), 325–342, https://doi.org/10.1080/10438590290020197
Beirao G., Sarsfield Cabral J.A. (2007) Understanding attitudes towards public transport and private car: A qualitative study. *Transport Policy*, 14(6), 478–489. https://doi.org/10.1016/j.tranpol.2007.04.009
Bell G.G. (2005) Clusters, networks, and firm innovativeness. *Strategic Management Journal*, 26(3), 287–295. https://doi.org/10.1002/smj.448.
Bellini F., Dulskaia I., Savastano M., D'Ascenzo F. (2019) Business Models Innovation for Sustainable Urban Mobility in Small and Medium-Sized European Cities. *Management and Marketing,* 14(3), 266–277. DOI:10.2478/mmcks-2019-0019
Benitez G.B., Ayala N.F., Frank A.G. (2020) Industry 4.0 innovation ecosystems: An evolutionary perspective on value cocreation. *International Journal of Production Economics*, 228, 107735 https://doi.org/10.1016/j.ijpe.2020.107735.
Bianchi M., Cavaliere A., Chiaroni D., Frattini F., Chiesa V. (2011) Organisational modes for Open Innovation in the bio-pharmaceutical industry: An exploratory analysis. *Technovation*, 31(1), 22–33 https://doi.org/10.1016/j.technovation.2010.03.002
Bigliardi B., Dormio A.I., Galati F. (2012) The adoption of open innovation within the telecommunication industry. *European Journal of Innovation Management,* 15(1), 27–54. https://doi.org/10.1108/14601061211192825
Bogers M., Zobel A.K., Afuah A., Almirall E., Brunswicker S., Dahlander L., Frederiksen L., Gawer A., Gruber M., Haefliger S., Hagedoorn J., Hilgers D., Laursen K., Magnusson M.G., Majchrzak A., McCarthy I.P., Moeslein R.M., Nambisan S., Piller F.T., Radziwon A., Rossi-Lamastra C., Sims J., Ter Wal A.L.J. (2017) The open innovation research landscape: Established perspectives and emerging themes across different levels of analysis. *Industry and Innovation*, 24(1), 8–40. https://doi.org/10.1080/13662716.2016.1240068
Breunig K.J., Aas T.H., Hydle K.M. (2014) Incentives and performance measures for open innovation practices. *Measuring Business Excellence,* 18(1), 45–54. https://doi.org/10.1108/MBE-10-2013-0049
Broekel T., Boschma R. (2012) Knowledge networks in the Dutch aviation industry: The proximity paradox. *Journal of Economic Geography*, 12(2), 409–433. https://doi.org/10.1093/jeg/lbr010
Burns L.D. (2013) A vision of our transport future. *Nature*, 497, 181–182. https://doi.org/10.1038/497181a
Carayannis E.G., Campbell D.F.J. (2009) 'Mode 3' and 'Quadruple Helix': Toward a 21st century fractal innovation ecosystem. *International Journal of Technology Management*, 46(3–4). DOI: 10.1504/ijtm.2009.023374.
Chesbrough H.W. (2003) *Open Innovation. The new imperative for creating and profiting from technology*, Cambridge, MA: Harvard Business Publishing.
Chesbrough H.W., Appleyard M.M. (2007) Open innovation and strategy. *California Management Review*, 50(1), 57–76. https://doi.org/10.2307%2F41166416.
Chong Z.J., Qin B., Bandyopadhyay T., Wongpiromsarn T., Rankin E.S., Ang M.H., Frazzoli E., Rus D., Hsu D., Low K.H. (2011) *Autonomous personal vehicle for the first- and last-mile transportation services.* Paper presented at the 2011 IEEE 5th International Conference on Cybernetics and Intelligent Systems (CIS) 17-19 September 2011, Qingdao, China. **DOI:** 10.1109/ICCIS.2011.6070337.
Cooper R.G. (2015) What's Next?: After Stage-Gate. *Research-Technology Management*, 57(1), 20–31. https://doi.org/10.5437/08956308X5606963
Dahl M.S., Pedersen C.Ø.R. (2004) Knowledge flows through informal contacts in industrial clusters: Myth or reality? *Research Policy*, 33(10), 1673–1689. https://doi.org/10.1016/j.respol.2004.10.004
Dahlander L., Gann D.M. (2010) How open is innovation? *Research Policy,* 39(6), 699–709. https://doi.org/10.1016/j.respol.2010.01.013
Delgado M., Porter M.E., Stern S. (2016) Defining clusters of related industries. *Journal of Economic Geography*, 16(1), 1–38. https://doi.org/10.1093/jeg/lbv017
Forza C. (2002) Survey research in operations management: A process-based perspective. *International Journal of Operations and Production Management*, 22(2), 152–194. https://doi.org/10.1108/01443570210414310
Fransman M. (2010) *The new ICT ecosystem: Implications for policy and regulation*, Cambridge (UK): Cambridge University Press.
Gassmann O., Enkel E. (2004) *Towards a theory of Open Innovation: Three core process archetypes*. 2004, Paper presented at the R&D Management Conference, January 2004. https://www.researchgate.net/publication/36384702_Towards_a_Theory_of_Open_Innovation_Three_Core_Process_Archetypes, accessed 20.07.2021.
Gawer A., Cusumano M.A. (2014) Industry platforms and ecosystem innovation. *Journal of Product Innovation Management*, 31(3), 417–433. https://doi.org/10.1111/jpim.12105
Gomes L.A., Facin A.L.F., Salerno M.S., Ikenami R.K. (2018) Unpacking the innovation ecosystem construct: Evolution, gaps and trends. *Technological Forecasting and Social Change*, 136(11), 30–48. https://doi.org/10.1016/j.techfore.2016.11.009
Graham-Rowe E., Skippon S., Gardner B., Abraham C. (2011) Can we reduce car use and, if so, how? A review of available evidence. *Transportation Research Part A: Policy and Practice*, 45(5), 401–418. https://doi.org/10.1016/j.tra.2011.02.001
Henn S., Bathelt H. (2015) Knowledge generation and field reproduction in temporary clusters and the role of business conferences. *Geoforum,* 58, 104–113. https://doi.org/10.1016/j.geoforum.2014.10.015
Hering S., Redlich T., Wulfsberg J.P., Bruhns F.-L. (2011) Open innovation in the automotive industry. *ZWF Zeitschrift fuer Wirtschaftlichen Fabrikbetrieb*, 106(9), 647–652.
Ho C.Q., Hensher D.A., Mulley C., Wong Y.Z. (2018) Potential uptake and willingness-to-pay for Mobility as a Service (MaaS): A stated choice study. *Transportation Research Part A: Policy and Practice*, 117, 302–318. https://doi.org/10.1016/j.tra.2018.08.025
Humphrey J., Schmitz H. (2002) How does insertion in global value chains affect upgrading in industrial clusters? *Regional Studies*, 36(9), 1017–1027. https://doi.org/10.1080/0034340022000022198
Iammarino S., McCann P. (2006) The structure and evolution of industrial clusters: Transactions, technology and knowledge spillovers. *Research Policy*, 35(7), 1018–1036. https://doi.org/10.1016/j.respol.2006.05.004
Iansiti M., Levien R. (2002) *The New Operational Dynamics of Business Ecosystems: Implications for Policy, Operations and Technology Strategy* (Harvard Business School Working Paper 03-030), Cambridge, MA: Harvard Business School Press. DOI: 10.1523/JNEUROSCI.1166-06.2006.
Iansiti M., Levien R. (2004) Strategy as Ecology. *Harvard Business Review*, March. https://hbr.org/2004/03/strategy-as-ecology, accessed 18.02.2021.
Ili S., Albers A., Miller S. (2010) Open innovation in the automotive industry. *R&D Management,* 40(3), 246–255. https://doi.org/10.1111/j.1467-9310.2010.00595.x
Jittrapirom P., Caiati V., Feneri A.M., Ebrahimigharehbaghi S., Alonso-Gonzalez M.J., Narayan J. (2017) Mobility as a service: A critical review of definitions, assessments of schemes, and key challenges. *Urban Planning*, 2(2), 13–25. DOI:10.17645/up.v2i2.931.
Kapoor R., Lee J.M. (2013) Coordinating and competing in ecosystems: How organizational forms shape new technology investments. *Strategic Management Journal*, 34(3), 274–296. https://doi.org/10.1002/smj.2010

Karim D.M. (2017) Creating an Innovative Mobility Ecosystem for Urban Planning Areas. In: *Disrupting Mobility* (eds. G. Meyer, S. Shaheen), Hedelberg, Dordrecht, London, New York: Springer, pp. 21–47. https://doi.org/10.1007/978-3-319-51602-8_2

Koen P.A., Bertels H.M.J., Kleinschmidt E.J. (2014) Managing the front end of innovation-part II: Results from a three-year study. *Research Technology Management,* May–June, 25–35. https://doi.org/10.5437/08956308X5703199

Lewin A.Y., Valikangas L., Chen J. (2017) Enabling Open Innovation: Lessons from Haier. *International Journal of Innovation Studies*, 1(1), 5–19. https://doi.org/10.3724/SP.J.1440.101002

Lines T., Monypenny R. (2006) *Industrial Clustering: A Literature Review*. https://www.researchgate.net/publication/238712690_Industrial_Clustering, accessed 10.07.2021.

Lyons G. (2018) Getting smart about urban mobility – Aligning the paradigms of smart and sustainable. *Transportation Research Part A: Policy and Practice*, 115, 4–14. https://doi.org/10.1016/j.tra.2016.12.001

Ma Y., Rong K., Mangalagiu D., Thornton T.F., Zhu D. (2018) Co-evolution between urban sustainability and business ecosystem innovation: Evidence from the sharing mobility sector in Shanghai. *Journal of Cleaner Production*, 188, 942–953. https://doi.org/10.1016/j.jclepro.2018.03.323

Marin R., Kaminski P.C., Armellini F., Bouchardy A. (2018) *Open Innovation practices in the automotive industry?: an exploratory comparison between Brazil and France* (SAE Technical Paper 2018-36-0210). https://doi.org/10.4271/2018-36-0210.

Monteiro F., Mol M., Birkinshaw J. (2017) Ready to be Open? Explaining the Firm Level Barriers to Benefiting From Openness to External Knowledge. *Long Range Planning,* 50(2), 282–295. https://doi.org/10.1016/j.lrp.2015.12.008

Moore J.F. (1993) Predators and prey: A new ecology of competition. *Harvard Business Review,* May–June. https://hbr.org/1993/05/predators-and-prey-a-new-ecology-of-competition, accessed 18.02.2021.

Mortara L., Minshall T. (2011) How do large multinational companies implement open innovation? *Technovation*, 31(10–11), 586–597. https://doi.org/10.1016/j.technovation.2011.05.002

Ning Z., Xia F., Ullah N., Kong X., Hu X. (2017) Vehicular social networks: Enabling smart mobility. *IEEE Communications Magazine*, 55(5), 16–55. DOI: 10.1109/MCOM.2017.1600263.

Oberg C., Alexander A.T. (2019) The openness of open innovation in ecosystems – Integrating innovation and management literature on knowledge linkages. *Journal of Innovation and Knowledge*, 4(4), 211–218. https://doi.org/10.1016/j.jik.2017.10.005

Parmentier G., Mangematin V. (2014) Orchestrating innovation with user communities in the creative industries. *Technological Forecasting and Social Change,* 83, 40–53. https://doi.org/10.1016/j.techfore.2013.03.007

Poudenx P. (2008) The effect of transportation policies on energy consumption and greenhouse gas emission from urban passenger transportation. *Transportation Research Part A: Policy and Practice*, 42(6), 901–909. https://doi.org/10.1016/j.tra.2008.01.013

Prettenthaler F.E., Steininger K.W. (1999) From ownership to service use lifestyle: The potential of car sharing. *Ecological Economics*, 28(3), 443–453. https://doi.org/10.1016/S0921-8009(98)00109-8

Pulkkinen J., Jussila J., Partanen A., Trotskii I., Laiho A. (2019) Smart Mobility: Services, Platforms and Ecosystems. *Technology Innovation Management Review*, 9(9), 15–24. DOI: 10.22215/timreview/1265.

Rabelo R.J., Bernus P. (2015) A holistic model of building innovation ecosystems. *IFAC-Papers OnLine*, 48(3), 2250–2257. https://doi.org/10.1016/j.ifacol.2015.06.423

Rajashekara K. (2013) Present status and future trends in electric vehicle propulsion technologies. *IEEE Journal of Emerging and Selected Topics in Power Electronics*, 1(1), 3–10. DOI: 10.1109/JESTPE.2013.2259614

Rohrbeck R., Holzle K., Gemunden H.G. (2009) Opening up for competitive advantage – How Deutsche telekom creates an open innovation ecosystem. *R&D Management,* 39(4), 420–430. https://doi.org/10.1111/j.1467-9310.2009.00568.x

Santos F.M., Eisenhardt K.M. (2005) Organizational boundaries and theories of organization. *Organization Science,* 16(5), 491–508. https://doi.org/10.1287/orsc.1050.0152

Sarkar S., Costa A.I.A. (2008) Dynamics of open innovation in the food industry. *Trends in Food Science and Technology*, 19(11), 574–580. https://doi.org/10.1016/j.tifs.2008.09.006

Sieg J.H., Wallin M.W., and von Krogh G. (2010) Managerial challenges in open innovation: A study of innovation intermediation in the chemical industry. *R&D Management,* 40(3), 281–291. https://doi.org/10.1111/j.1467-9310.2010.00596.x

Smith G., Sochor J., Karlsson I.C.M.A. (2018) Mobility as a Service: Development scenarios and implications for public transport. *Research in Transportation Economics*, 69, 592–599. https://doi.org/10.1016/j.retrec.2018.04.001

Sturgeon T.J., van Biesebroeck J. (2011) Global value chains in the automotive industry: An enhanced role for developing countries? *International Journal of Technological Learning, Innovation and Development*, 4(1–3), 181–205. DOI: 10.1504/IJTLID.2011.04190

Swann P., Prevezer M. (1996) A comparison of the dynamics of industrial clustering in computing and biotechnology. *Research Policy*, 25(7), 1139–1157. https://doi.org/10.1016/S0048-7333(96)00897-9

Teece D.J. (2018) Profiting from innovation in the digital economy: Enabling technologies, standards, and licensing models in the wireless world. *Research Policy,* 47(8), 1367–1387. https://doi.org/10.1016/j.respol.2017.01.015

Thompson V., Hardash J.A.C., Decker B., Summers R.O. (2012) *NASA (In)novation ecosystem: Taking technology innovation from buzz to reality*. Paper presented at the 2012 IEEE Aerospace Conference, 3-10 March 2012, Big Sky, MT, USA. DOI: 10.1109/AERO.2012.6187447.

Torre A. (2008) On the Role Played by Temporary Geographical Proximity in Knowledge Transmission. *Regional Studies*, 42(6), 869–889. https://doi.org/10.1080/00343400801922814

Torre A. and Zimmermann J.-B. (2015) From clusters to local industrial ecosystems. *Revue d'economie industrielle*, 52, 13–38, DOI: 10.4000/rei.6204.

Traitler H., Watzke H.J., Saguy I.S. (2011) Reinventing R&D in an Open Innovation Ecosystem. *Journal of Food Science*, 76(2), R62–68, https://doi.org/10.1111/j.1750-3841.2010.01998.x

Walsh J.P., Lee Y.N., Nagaoka S. (2016) Openness and innovation in the US: Collaboration form, idea generation and implementation. *Research Policy,* 45(8), 1660–1671. https://doi.org/10.1016/j.respol.2016.04.013

West J., Bogers M. (2014) Leveraging external sources of innovation: A review of research on open innovation. *Journal of Product Innovation Management*, 31(4), 814–831. https://doi.org/10.1111/jpim.12125

West J., Salter A., Vanhaverbeke W., Chesbrough H. (2014) Open innovation: The next decade. *Research Policy*, 43(5), 805–811. https://doi.org/10.1016/j.respol.2014.03.001

Wilhelm M., Dolfsma W. (2018) Managing knowledge boundaries for open innovation – lessons from the automotive industry. *International Journal of Operations & Production Management*, 38(1), 230–248. https://doi.org/10.1108/IJOPM-06-2015-0337

Wright M.,Train K. (1987) Qualitative Choice Analysis-Theory, Econometrics and an Application to Automobile Demand. *The Journal of the Operational Research Society*, 38(7), 665. https://doi.org/10.2307/2582403

Wu G., Inderbitzin A., Bening C. (2015) Total cost of ownership of electric vehicles compared to conventional vehicles: A probabilistic analysis and projection across market segments. *Energy Policy*, 80, 196–214. https://doi.org/10.1016/j.enpol.2015.02.004

Yang C.H., Motohashi K., Chen J.R. (2009) Are new technology-based firms located on science parks really more innovative? Evidence from Taiwan. *Research Policy*, 38(1), 77–85. https://doi.org/10.1016/j.respol.2008.09.001

Innovation Policy Learning in Iran's Development Plans

Kiarash Fartash
Assistant Professor [a], k_fartash@sbu.ac.ir

Mahdi Elyasi
Associate Professor [b], elyasi.atu@gmail.com

Amir Ghorbani
Policy Officer [c], and Researcher [a], amirghorbani1373@yahoo.com

Ali Asghar Sadabadi
Assistant Professor [a], a_sadabadi@sbu.ac.ir

[a] Institute for Science and Technology Studies, Shahid Beheshti University, Daneshju Blvd, Evin Square, Tehran 1983963113, Iran

[b] Faculty of Management and Accounting, Allameh Tabataba'i University, Dehkade-ye Olampik, West Hemmat Highway, Tehran, 1489684511, Iran

[c] Vice-Presidency for Science and Technology, No 20, Ladan alley, North Sheikh Bahayee St., MollaSadra St., Vanak Sq., Tehran 1991745681, Iran

Abstract

Apart from "future-shaping" tools (such as forecasting, scenario planning, etc.), many countries also use "backward-looking" approaches to develop long-term strategies for switching to a new economic model. A retrospective assessment of accomplishments and failures (or policy learning, PL) helps one learn lessons and improve the effectiveness of innovation policy. Using the example of Iran, this paper examines the use of PL to assess key initiatives in the field of science, technology, and innovation over the past two decades. Field research allowed the authors to identify the main policy goals, analyze their evolution and the changes in the perception of previously made decisions by politicians themselves. The active use of technical and conceptual PL indicates relative progress made in adjusting the policy vector. At the same time, partisan policy learning remains common, applied to legitimize the current course, which indicates the insufficient maturity of Iran's political system (as is the case in many other developing countries). It was concluded that to make real progress and increase the effectiveness of innovation policy, technical and conceptual aspects should be applied, while keeping the use of partisan policy learning to a minimum.

Keywords: policy learning; challenges; lessons; development strategy; foresight; Republic of Iran; technology and innovation policy

Citation: Fartash K., Elyasi M., Ghorbani A., Sadabadi A.A. (2021) Innovation Policy Learning in Iran's Development Plans. *Foresight and STI Governance*, 15(3), 81–92. DOI: 10.17323/2500-2597.2021.3.81.92

Introduction

Shaping and implementing science, technology, and innovation policy plays a key role in switching to a new economic model. Various tools are applied to enrich national, corporate, and individual strategies, including retrospective analysis and learning from previous accomplishments and failures (policy learning, PL). History is analyzed in terms of the past choices' impact on future scenarios [*Schoemaker,* 2020]. PL sheds light on the process of shaping science, technology, and innovation policy, helps its developers and experts understand the context in which strategic decisions were made, learn lessons, grasp the essence of the learning process itself, and change politicians' views on the appropriateness of particular steps.

The theoretical foundations of PL were consistently developed in [*Heclo*, 1974; *Sabatier*, 1988; *Bennett, Howlett,* 1992; *May,* 1992; *Hall,* 1993]. Since the 1980s its application was extended from public administration to other areas. Over time PL has become part of a systematic approach to innovation [*Klochikhin,* 2013] and innovation policy [*Biegelbauer,* 2016; *Borras,* 2011; *Braun, Benninghoff,* 2003; *Schwerin, Werker,* 2003].

The use of PL for strategic planning in the context of developing economies is not sufficiently covered in the literature [*Freeman,* 1987; *Kim,* 1997]. Using the example of Iran, this paper examines this process in relation to the shaping of national science, technology, and innovation policy in 2000-2021.

A retrospective review of Iran's past development plans provides an insight into how and why "looking back" can help one "look forward". Strategic planning in Iran began in the middle of the last century [*Bostock, Jones,* 2014]. So far 10 national development plans have been consistently adopted: five before the 1979 revolution and five after it. The last four plans, implemented since the early 2000s, included specific science and technology sections. Some of the targets set there, such as increasing the share of gross domestic expenditures on research and development (GERD) in GDP, total factor productivity (TFP), and protecting intellectual property (IP) still remain relevant, while others were transformed into other, new objectives.

Literature Review

Approaches to learning lessons for use in making strategic decisions are being actively studied in the scope of various research fields such as organizational studies [*Argote*, 2012], the theory of the firm [*Penrose*, 1959], evolutionary economics [*Nelson, Winter,* 1982], and technological capabilities [*Salisu, Bakar,* 2019]. The concept of PL has expanded from public administration [*Sabatier,* 1988] to other areas including science, technology, and innovation policy studies [*Murrall-Smith,* 2011, *Biegelbauer,* 2016, *Sanderson,* 2002; *McCann, Ward*, 2012]. Depending on the context, PL can be collective [*Hall,* 1993] or individual [*Heclo,* 1974]. [*Hall,* 1993] presents a classification of PL types applied to shape economic and innovation policy in the UK. The author identified three types of policy learning. The first one (*technical PL*) helps to develop and improve policy tools; the second (*conceptual*) implies adjusting policy goals and objectives, while the third (*social*) helps adjust the strategic vector and basic attitudes. Examples of the use of PL in different countries can be found in [*Murrall-Smith,* 2011; *Biegelbauer*, 2016].

Lieu [*Lieu,* 2013] mentions *technical* PL aimed at improving policy tools and programs and *conceptual* PL carried out to adjust strategic goals and directions. The main PL mechanisms include systemic study, observation, experimentation, and collaboration. In Austria, a combination of five PL types proved to be highly effective in innovation policy shaping: social, reflexive, partisan, technical, and managerial PL [*Biegelbauer,* 2016]. The European Commission used PL at the organizational and personal levels to assess the integration of climate policies in member states. *Factual* policy learning extended the understanding of the situation, *constructivist* PL revealed changes in norms, values, and beliefs, while *experimental* PL helped with solving specific problems, gaining experience, and understanding the successes or failures of particular decisions [*Rietig, Perkins,* 2017].

Unlike other PL types, *partisan* policy learning does not aim to improve policy [*Oliver, Pemberton,* 2004] or focus on the long term. Its primary functions are managing the current context and minimizing the risks for the current authorities [*May,* 1992; *Nilsoon,* 2005; *Baily, Compston,* 2010]. A similar approach was used in the 1970s in the UK to promote renewable energy sources (RES). Political declarations have never produced any real results [*Murrall-Smith,* 2011]. Studies show that in more mature political systems, the demand for *technical*, *conceptual*, and *social* PL increases [*Moyson et al.,* 2017].

Methodology

In the Iranian context, due to the lack of important tacit information, case studies were seen as the best approach to assessing policy learning's contribution to strategic planning [*Yin,* 2013]. More important science, technology, and innovation policy areas were identified, the corresponding sections of the economic development plans approved in the last two decades analyzed, and the main PL types, mechanisms, and participants described. The tools used to collect field data included semi-structured interviews, expert publications, development plans, and an analysis of the research and development (R&D) sphere [*Suurs et al.*, 2009]. Officials, experts,

Table 1. **Policy Learning Types**

Categories of Policy Learning	Technical	Conceptual	Political	Social
Subject/ content of learning	Effectiveness and feasibility of instruments	Defining problems, goals and strategies	New strategies for supporting specific goals	Values, duties, relations and multiple approaches
Examples of policy learning	Adjustment in instruments/ standards	Adjustment of new problems and past goals	Symbolic (usually not stable) adjustments over time	Collaboration with stakeholders and testing new mechanisms of cooperation
Evidence of policy learning	Referring and describing evaluations and behaviors	New systematic problems, goals, and descriptions	New tactics in policy discussions	–

Source: [*Murrall-Smith,* 2011].

scientists, and practitioners involved in the development, approval, and implementation of the plans were interviewed (Tables 2 and 3). The questions asked during the interviews concerned changes in the development goals and areas, visions of the innovation policy vector, arguments used by supporters and critics of various initiatives, ways to obtain relevant competencies, and key participants in the system. In the case of a contradiction in the respondents' assessments, the most common opinion was taken into account. Sixteen innovation system-related strategic goals were identified in the resulting data array for further study (Box 1).

Implementation of Innovation Policy in the Economic Development Plans

Iran started the systematic planning of economic development in 1948, before most of its peers at the time (such as China, the Republic of Korea, or India) [*Mc Leod,* 1964; *Baldwin,* 1967]. Five economic development plans were consistently put into effect between 1948-1979 (the beginning of the Islamic revolution), but the objectives were fully implemented only in the case of the third (and partly the fourth) plan. The last two plans were focused on industrial development based on technology transfer and import substitution. The implementation of the sixth plan was cut short with the onset of the revolution followed by the war with Iraq. As a consequence, throughout the 1980s support for higher education, science, technology, and innovation was not present on the political agenda. As the situation stabilized, the attitude toward the content of economic plans changed. The promotion of science, technology, and innovation has been renewed since the late 1990s [UNCTAD, 2016]. The agency responsible for drafting the plans (the Planning and Budget Organisation, PBO) was restructured. The first two plans drawn up in the new period were focused on developing higher education and coordinating innovation actors' efforts (respondents 2, 11, and 13). New, more ambitious goals have been added to the previously set ones, which reflects insufficient policy learning in the R&D sphere. Since the 2000s (and the adoption of the third plan), science, technology, and innovation were addressed in a separate section.

Box 1. **Innovation Policy Goals Subjected to Policy Learning**

1. Improving local content and public procurement in favor of T&I development
2. Formulation and implementation of industrial policy
3. Coordination and coherence among STI policy actors
4. STI development policies and systematic approach to innovation policy
5. Enforcing intellectual property rights (IPRs)
6. Commercialization and trading IPRs
7. Expanding international technological collaborations and absorbing foreign T&I investment
8. Developing intermediaries for T&I development (such as S&T parks, incubators, and technology districts)
9. Supporting SMEs, promoting their growth and linkages to large firms
10. Promoting private research and technology (R&T) funds as well as VC funds
11. Insurance of R&T activities
12. Supporting demand- and mission-based research and innovation
13. R&D share of GDP
14. Supporting R&D activities
15. Supporting the creation of technology-based firms affiliated with universities (university spin-offs)
16. Encouraging the development of high-tech technologies (both generally and thematically)

Source: authors.

Table 2. **Respondents Interviewed during the Study**

№	Interviewee	Date	Involvement into the plan preparation			
			3rd	4th	5th	6th
1	Senior researcher, member of RTTG	12-03-2016		*	*	
2	Senior expert at PBO, member of RTTG	07-03-2017, 12-04-2021	*	*	*	*
3	Senior civil servant at VPST & MIMT	26-01-2016	*	*		
4	Senior policy consultant, member of RTTG	15-02-2016		*	*	
5	Senior civil servant at PBO	22-02-2016, 14-04-2021	*	*	*	*
6	Former minister	03-05-2016	*	*		
7	Senior civil servant at VPST	17-05-2016			*	
8	Former vice-minister	24-05-2016	*	*		
9	Former vice-president	05-06-2016		*		
10	Civil servant and policy expert	07-06-2016		*	*	
11	Former senior civil servant at PBO	15-06-2016, 08-04-2021	*	*	*	*
12	Senior policy consultant and expert	23-06-2016	*	*	*	
13	Senior civil servant at PBO	29-06-2016	*	*		
14	Policy researcher, faculty member	22-04-2017, 06-04-2021	*	*	*	*
15	Senior civil servant at parliament research center	09-05-2017, 10-04-2021		*	*	*

Note: The PBO is the lead agency responsible for drafting economic development plans to be approved by the government and parliament. Every five years the PBO hosts an RTTG meeting; the latter group drafts the science, technology, and innovation sections of the plan over a period of about a year. The RTTG comprises representatives of MSRT, VPST, MICT, MoD, MoE, MoA, MIMT, and ACECR. Please refer to Table 3 for explanations of the abbreviations.

Source: authors.

Iran, with its substantial oil and gas reserves, managed to avoid "resource dependence". Over the past decade, industrial production has grown in scale and diversity, so the national economy has become the most diversified among the Middle Eastern countries (the oil and gas sector's share is less than 20% of GDP) [UNCTAD, 2016; McKinsey, 2016].

Three main stages can be identified in the development of Iran's science, technology and innovation policy [*Heshmati, Dibaji,* 2019, UNCTAD, 2016].

- **In the 1990s** priority was given to transforming and developing higher education infrastructure.
- **In the 2000s** the focus shifted to promoting R&D in areas such as bio-, nano-, information, and cognitive technologies.
- **In the 2010s** the transition to a knowledge-based economy, the commercialization of technologies, and supporting high-tech companies came to the fore [*Soofi, Ghazinoory,* 2013, *Souzanchi, Kashani,* 2020].

The main innovation policy areas are presented in Table 4.

Systemic efforts to transform the national economy by promoting the development of science, technology, and innovation have improved statistical indicators. In 2005-2019 significant progress was made in the development of higher education, increasing industrial product exports, and upgrading the information and communication technology (ICT) infrastructure. Though the share of GERD in Iran's GDP did not grow during that period, R&D was actively conducted in new areas including nano- and biotechnology and renewable energy sources. In terms of the number of academic publications, in 2005 Iran was 34th and in 2019 it climbed to 15th place[1]; in terms of the number of papers on nanotechnology it was 4th.[2] The number of patent applications grew from 4,494 in 2005 (28th place) to 12,147 in 2019 (16th).[3]

In 2014-2019 Iran has moved up 59 places in the Global Innovation Index, from 120th to 61st place [*Dutta et al.,* 2020]. The total capacity of power plants operating on renewable energy sources in 2020 amounted to 920 MW (twice as much as in 2017) [*Fartash et al.,* 2021]. The Iranian National Innovation Fund[4] actively supports high-tech product manufacturers; since 2001 it has financed over 5,870 companies with a total turnover of about 28.5 billion USD in 2020.

Third Economic Development Plan (2000-2004)

With the adoption of the law on "maximizing the use of domestic capabilities", the development of an R&D strategy acquired a systemic basis and was described in a separate section of the economic development plan [UNCTAD, 2016]. While previous

[1] https://www.scimagojr.com/countryrank.php, accessed on 30.03.2021.

[2] https://statnano.com/report/s29, accessed on 30.03.2021.

[3] https://www3.wipo.int/ipstats/index.htm?tab=patent, accessed on 30.03.2021.

[4] Established in 2001 with initial capital of 3 billion USD. For more see: https://pub.daneshbonyan.ir, accessed on 30.03.2021.

Table 3. **List of Organizations Mentioned in Table 2**

Name	Acronym
Planning and Budget Organization	PBO
Research and Technology Task Group	RTTG
Ministry of Science, Research and Technology	MSRT
Vice-Presidency for Science and Technology	VPST
Ministry of ICT	MICT
Ministry of Defense	MoD
Ministry of Power	MoP
Ministry of Agriculture	MoA
Ministry of Industry, Mines and Trade	MIMT
Iranian Academic Center for Education, Culture and Research	ACECR
Source: authors.	

programs did provide for developing new technologies and competencies, they were not sufficiently consistent and specific. The authors of the law set the goal to promote technological cooperation with foreign companies (respondents 2 and 5). The policy vector pursued in the late 1990s was recognized as a mistake. To better coordinate the work, the Ministry of Culture and Higher Education was transformed into the Ministry of Science, Research, and Technology and was given extended powers (respondents 6, 8, and 11). However, this decision is now also seen as unproductive.

Significant resources were allocated to support private research foundations and companies. Publicly funding half of the costs of demand-driven research by universities was an initiative that counts as a successful one and was renewed in subsequent economic development plans (respondents 4, 11, 13). Universities were allowed to establish high-tech companies and own a controlling interest in them. A radical change in the attitude toward promoting R&D development was reducing the role of the state and encouraging the private sector (respondent 2). Given that after the revolution the nationalization of large enterprises and banks was stepped up, this university reform was evidence of active *conceptual* PL. The third plan was implemented in the context of low oil and gas prices and allowed the country to avoid an economic downturn. Its overall implementation is estimated at about 50% and the implementation of the R&D-related sections was above average (respondents 2, 5, and 11).

The fourth, fifth, and sixth plans lacked clear, realistic goals. Their content was a rather chaotic medley of diverse political objectives and tools, including attracting foreign direct investment, promoting the commercialization of R&D results and international technological cooperation, and the development of the national innovation system as a whole (respondents 1, 2, and 11).

Fourth Economic Development Plan (2004-2009)

Unlike the previous one, the fourth plan was developed in the context of high energy prices. A wide range of poorly coordinated ideas and initiatives were proposed for inclusion, so their harmonious integration into a five-year cycle turned out to be problematic (respondent 9). The key goals and visions looked unrealistic and utopian. At the same time, it was recognized that changing the economy's focus from natural resources to research and knowledge could only be based on increasing TFP

Table 4. **Main Innovation Policy Initiatives**

Policy	Year of ratification	Ratified by	Objectives
2025 Vision: 20-year Vision Plan	2005	Supreme Leader	Providing desired status of Iran, including STI, for a 20 year period
The Law of Registration of Patents, Industrial Designs, and Trademarks	2007	Parliament	Protection of intellectual property rights
Law for Supporting Knowledge-based Firms and Commercializing Innovations	2010	Parliament	Supporting KBFs to facilitate transition to a knowledge-based economy
National Master Plan for Science and Education	2011	Supreme Council for the Cultural Revolution	Presenting objectives, policies, strategies, structures, and requirements for the development of T&I until 2025
National Policy for S&T 2014 and National Policy for a Resilient Economy	2014	Supreme Leader	Providing a holistic framework policy for supporting T&I development and industrialization
Development plans (containing STI-related articles)	6th plan approved in 2017	Parliament	The most comprehensive framework policy of Iran for a five-year period to fulfill the 2025 vision, overarching all other national policies, to spearhead the development of Iran in all aspects including STI
Act of Maximum Use of Production and Services to Satisfy the Country's Needs and Enhance Them in Exports	1996, revised in 2012 & 2019	Parliament	Supporting local content and active role of domestic firms in international projects to enhance their capability
Source: authors basing on [*Soofi, Ghazinoory,* 2013; UNCTAD, 2016; *Souzanchi, Kashani,* 2020].			

through intensive innovation development (respondents 5 and 9). The implementation of the law on maximizing the use of national capabilities remained a priority. Compared to previous plans, the promotion of the "technological" vector and improving the domestic value chains was considerably stepped up, in line with the highly open economic policy at the time. The focus was on promoting the growth of small and medium-sized enterprises (SMEs), strengthening their links with big businesses, developing value chains in industrial clusters, supporting technology parks, and creating special technology zones. The national innovation system's productivity was supposed to be increased through the institutional modernization of the R&D sphere, including strengthening intellectual property protection, improving research infrastructure, stepping up commercialization, and creating a technology brokers' institution. Support for private foundations and science and technology projects aiming to meet actual demand was expanded.

Fifth Economic Development Plan (2011-2017)

A local version of the US Bayh-Dole Act (1980) was adopted. Priority was given to an integrated industrial development strategy, strengthening the country's technological potential, and gaining a competitive edge. The focus was on protecting intellectual property and encouraging universities and research organizations to establish private knowledge-intensive start-ups. Note that according to previous plans, such companies could be exclusively owned by universities.

Sixth Economic Development Plan (2017-2021)

As was the case with the previous plan, the parliament had to overcome the government's reluctance to approve it (respondents 2, 9 and 12). Initially the government committed to fully implementing the economic development plans, but then found a way to get around this obligation (respondents 2 and 12). The provisions of the fifth and sixth plans essentially coincide with the fourth one. They were relatively proactive and endogenous, with the exception that the executive authorities were officially allowed to implement the initiatives specified in the plans selectively. Export promotion and integration into global value chains were brought to the fore, along with public procurement to promote R&D, support for small and medium-sized businesses, and strengthening their ties with large companies. Continuity has been maintained with the fifth plan regarding intellectual property and research-intensive university start-ups. The sixth plan is mainly focused on promoting R&D potential through international cooperation and attracting foreign direct investment. The effort to engage the private sector in developing high-tech projects was stepped up.

The Use of Policy Learning in Drafting Economic Development Plans

Key aspects of innovation were identified through a content analysis of the plans, policy documents, drafts, and reports prepared by the Research and Technology Task Group (RTTG). The R&D-related development goals were identified using two main criteria:

- feasibility of the science, technology, and innovation objectives (assessed mainly on the basis of the comments of the respondents directly involved in drafting the plans, and partly by analyzing the wording of the documents)
- presence in at least two plans.

The goals of the last four plans presented in Tables 5-8 were identified primarily from their approved versions, and the final RTTG report. Table 9 indicates relevant PL types, the participants who conducted it, and the mechanisms applied to adjust the policies.

The fact that policy tools have been modified indicates that *technical* policy learning took place, while a change in benchmarks suggests the use of *conceptual* PL. We learned about *social* and *partisan* policy learning mainly from the respondents' comments. Changes in the nature of political dialogue on particular issues indicate *social* PL.

Partisan policy learning was confirmed by policymakers' justifying and maintaining their legitimacy. PL of various types was carried out in relation to the 16 basic policy goals (see Box 1). The only case of *social* PL was discovered, resulting in a changed attitude toward the knowledge economy and knowledge-intensive companies and the emergence of a common position to provide comprehensive support for them. Six cases of *partisan* policy learning were established with the objective of strengthening legitimacy by making minor adjustments to strategies. *Technical* PL was revealed in seven basic areas, leading to the development of improved and diversified policy tools (the exact opposite of *partisan* PL). The seven cases of *conceptual* policy learning indicate a willingness to align goals with the requirements of technological and innovative development.

All in all, Iran has not been successful in accomplishing the targets set in the economic development plans (respondents 1, 2, 8, and 11). The fact that these targets were transferred into subsequent plans essentially unchanged indicates an awareness of their relevance and ongoing efforts (albeit unsuccessful) to accomplish them. The frequency of *partisan* learning indicates attempts to maintain legitimacy by transferring unfulfilled tasks to the next

Table 5. **Status of the Considered Policy Issues in the 3rd Plan (2000–2004)**

Policy issue	Status in the 3rd plan
1	Abiding by MULC law (A5 88); minimum of 10% share of local content in international contracts (A 89)
2	*No direct implication*
3	Establishment of MSRT as the main coordinator among T&I policy actors (A 99)
4	*No direct implication*
5	Preparing bill of IPR law one year after approval of plan (executive solutions, 15 in S&T section)
6	*No direct implication*
7	*No direct implication*
8	*No direct implication*
9	*No direct implication*
10	Facilitating establishment of private R&T funds and supporting them (A 100)
11	Providing supportive insurance for R&T development activities of private research organizations (A 101)
12	Funding up to 60% of research projects that have demand from a governmental organization and are carried out by universities and research organizations (A 102)
13	1.5% of which two thirds should be funded by government with a 15% share of basic research (A 102)
14	Providing the private sector with incentives to increase their engagement in R&D activities (A 102)
15	Authorization of universities to establish governmental R&T-intensive firms with up to 49% ownership held by university staff (A 154)
16	Supporting establishment of firms involved in advanced technology development (A 171)

Note: In the tables 5-8, A means Article associated with each policy in development plans.
Source: authors.

Table 6. **Status of the Considered Policy Issues in the 4th Plan (2004–2009)**

Policy issue	Status in the 4th plan
1	Abiding by MULC law (A 42); abiding MULC in all international contracts (A 13); public procurement directed toward technology development (A 37)
2	Formulating an industrial policy to improve technological capabilities and spillovers (A 21)
3	*No direct implication*
4	Formulation and implementation of NIS (A 46); formulating a holistic research and technology development system (A 43)
5	Design and implementation of a comprehensive IPRs system (A 45)
6	Putting into effect mechanisms for IP valuation and trade (A 45)
7	Developing effective international technological collaboration supports and mechanisms (A 46); developing incentives to encourage foreign investment directed toward T&I development (A 48)
8	Developing institutional infrastructures for promoting knowledge-based activities such as S&T parks and incubators (A 45); extending incentives provided to free economic zones to firms located in S&T parks (A 47)
9	Enhancing linkages between SMEs and big firms (A 39); removing barriers impeding the growth of big firms (A 39); developing industrial networks and clusters to boost manufacturing (A 39)
10	Supporting the establishment and growth of private R&T funds (A 45); support the creation and development of technology financing mechanisms such as VC funds (A 40)
11	Designing proper mechanisms for insuring T&I development activities (A 50)
12	Funding up to 60% of research projects that have private sector demand and are carried out by universities and research organizations (A 45); directing R&D activities toward demand- and mission-based projects (A 46)
13	2% funded entirely by the government (A 46);
14	Providing financial and non-financial incentives to increase the involvement of SMEs in R&D activities (A 45)
15	Authorization of universities to establish governmental R&T-intensive firms with up to 49% ownership held by university staff (A 51)
16	Taking measures to improve domestic absorptive capacity in advanced technologies (A 40); adopt a plan to improve technology development in areas such biotech; nano, ICT, nuclear, and environment (A 43)

Source: authors.

Table 7. **Status of the Considered Policy Issues in the 5th Plan (2010–2015)**

Policy issue	Status in the 5th plan
1	Abiding by MULC law (A 150); priority of public procurement from local firms (A 78); facilitation of local content (A 150)
2	Formulating an industrial policy supporting enhanced industrial manufacturing and value added (A 150)
3	Coordination among T&I policy actors in policymaking and supervision by MSRT and SCSRT6 (A 16)
4	Implementation of national master plan for science and education (A 6); formulating an Islamic-Iranian development model (A 1)
5	Changing IPR evaluation system from declarative to assessment-based (A 17)
6	Establishment of IP stock market (A 17); supporting manufacturers to acquire IP (A 17); transferring ownership of IP in projects funded by government to universities and research organizations (A 17)
7	Promoting technological international collaboration to acquire know-how and encourage foreign firms to bring some of their R&D facilities to Iran (A 17)
8	Supporting the establishment of private S&T parks & incubators (A 17)
9	Supporting the creation of technological startups (A 17); developing brokers to link SMEs and big firms and facilitate commercialization by startups and their acquisition by big firms (A 17 & 80); improving linkages of SMEs and big firms which aids in the development of industrial networks, clusters, and local content (A 80)
10	Support VC funds by providing them with managed funds annually (A 151)
11	*No direct implication*
12	Funding up to 50% of research projects that have demand from a non-governmental organization and are carried out by universities and research organizations (A 102)
13	3% with annual increase of at least 0.5% (A 16)
14	Facilitate access of private technology-based firms to research labs and R&D facilities (A 17)
15	Faculty members at universities are authorized to establish R&T-intensive firms with the approval of university boards of trustees (A 17)
16	Leveraging advanced technology development to improve industrial competitiveness and added value (A 150); acquiring know-how in areas such as petrochemical; biotech, nano, ICT and microelectronics (A 129 & 197)

Source: authors.

Table 8. **Status of the Considered Policy Issues in the 6th Plan (2016–2021)**

Policy issue	Status in the 6th plan
1	Maximum utilization of local content to strengthen technological learning and capability (A 51)
2	Enhancing domestic industrial capabilities through entering GVCs (A 4)
3	*No direct implication*
4	Achieving one fourth of national productivity by improving TFP (A4)
5	Enhancing IPR enforcement at the firm level (A 4)
6	Supporting research commercialization (A 4)
7	Leveraging foreign investment and projects managed by MNCs to enhance domestic technological capability (A 4; A 51; A64)
8	Improving STI diplomacy (A 105)
9	Supporting the establishment of private technology towns (A 74)
10	Supporting and empowering knowledge-intensive firms in production and export (A 51)
11	Establishment of high-tech fund under the MIMT (A 69)
12	*No direct implication*
13	Funding up to 50% of research projects that have demand from and are done by universities and research organizations (A 64); Creation and stimulation of demand for knowledge-intensive products (A 51)
14	3% by 2021
15	All governmental organizations and firms should spend at least 1% and 3% of their annual budget and income, respectively, on R&D (A 64)
16	Faculty members at universities are authorized to establish private R&T-intensive firms (A 1)

Source: authors.

Table 9. **Findings on Technology and Innovation Policy Issues and their Associated Policy Learning**

No.	Policy issue	Type of learning	Actors involved	Learning mechanisms
1	Improving local content and public procurement in favor of T&I development	TPL; PPL	CS; PE&C; HO	EIPP; DI; T&LD
2	Formulation and implementation of industrial policy	TPL; PPL	CS; PE&C; HO	T&LD; DI
3	Coordination and coherence among STI policy actors	PPL	CS; HO; PE&C; RTTG	T&LD; EIPP; DI
4	STI development policies and systematic approach to innovation policy	SPL; PPL	CS; HO; PE&C; RTTG	T&LD; DI
5	Enforcing IPRs	TPL	RTTG; CS; PE&C	EIPP; DI
6	Commercialization and trading IPRs	TPL	RTTG; CS; MoA	EIPP; T&LD; DI
7	Expanding international technological collaboration and absorbing foreign T&I investment	CPL	RTTG; CS	EIPP; T&LD
8	Developing intermediaries for T&I development (such as S&T parks, incubators, and technology districts)	CPL	RTTG; PA; CS; HO	EIPP; T&LD
9	Supporting SMEs, promoting their growth and linkages with big firms	TPL; CPL	CS; PE&C	EIPP; PPE
10	Promoting private research and technology (R&T) funds as well as VC funds	TPL; CPL	RTTG; CS; PE&C	EIPP; T&LD
11	Insurance of R&T activities	CPL	RTTG; CS	T&LD;
12	Supporting demand- and mission-based research and innovation	CPL	RTTG; CS; PE&C	EIPP;
13	R&D share of GDP	PPL	RTTG; CS	EIPP; T&LD
14	Supporting R&D activities	PPL	RTTG; CS	EIPP;
15	Supporting the creation of technology-based firms affiliated with universities (university spin-offs)	CPL; SPL	RTTG; PA: HO:	EIPP; DI
16	Encouraging the development of high-tech technologies (both generally and thematically)	TPL;	RTTG: CS; HO	T&LD; DI

Legend:
TPL: Technical policy learning
CPL: Conceptual policy learning
PPL: Political policy learning
SPL: Social policy learning
RTTG, MoA — see description at Table 3
CS: Civil servants at member organizations in RTTG
PE&C: Policy experts and wider policy communities including media, academics, consultants, and policy entrepreneurs
PA: Public authorities beyond government including judiciary, parliament, and public organizations
HO: High level officials at least at vice-ministerial level
T&LD: Systemic practical and academic training as well as lesson drawing from other countries
PPE: Previous related policy experience
EIPP: Evaluation and implementation of previous plans
DI: Discussions and interactions among policy actors.

Source: authors.

plans intact or in an even more ambitious format. This issue is typical for developing countries and without dealing with it, achieving tangible science, technology, and innovation policy results would be impossible [*Compston,* 2010, *Casady, Parra,* 2020].

Discussion

Now we will discuss the similarities and differences between our results and the practices described in the literature as well as their applicability to other developing countries. Iran's situation is similar to the one described in [*May,* 1992]: policymakers do not see the pragmatic adjustment of policy goals and tools as a priority, but focus on strengthening their own legitimacy through rhetoric and declarations of commitment to the set goals [*Murrall-Smith,* 2011]. A similar situation is also observed in certain African countries which also update their national development plans every few years. Despite the declared goals to increase the share of GERD in GDP, sufficient funds to promote R&D are not actually allocated, while relevant official statistics are not published [*Siyanbola et al.,* 2016; *Oladeji, Adegboye,* 2019].

In contrast to *partisan* PL, *social* policy learning is much less common in Iran. Our study revealed its application in relation to only two policy goals, which is again typical for other countries. For example, in Lebanon the government has implemented at least five science, technology, and innovation development plans, but the situation remains largely unchanged [*Gaillard,* 2010].

Nevertheless, positive changes have also been noted in Iran. Over the past five years the dialogue on the relevance of creating innovations domestically has been strengthening and is being taken very seriously; concerns about the transition to a new economic model are growing. These issues are discussed by the general public and taken into account through *social* policy learning.

Since 2010 the attention paid to science, technology, and innovation has grown significantly. After the lifting of the sanctions imposed on Iran in 2016, the government introduced special requirements for the "technology section" of the plans, including the requirement to conduct R&D in the scope of all international contracts. An example of a systemic approach is encouraging the innovation-based development of universities. *Technical* and *conceptual* policy learning were applied more often than other types (seven times each). *Technical* PL did not imply changing policy goals but helped to improve the tools for their implementation. There are known examples of its application in shaping innovation policy in Malaysia, Singapore [*Lim,* 2018, *Narayanan, Yew-Wah,* 2018], and other countries [*Smits, Kuhlmann,* 2004; *Boekholt,* 2010]. *Conceptual* policy learning changes policy vision, its scope, and target groups. Priority was given to international cooperation, providing support for R&D projects in various forms, linking them to actual demand, and focusing on accomplishing the set goals. Over the past two decades, this type of policy learning has led to a shift in political emphasis from research to technology development, and in the past six years, to innovation (including the abandonment of a linear approach to creating innovations in favor of building an innovation system). The focus on increasing supply is giving way to initiatives to promote demand. There were important changes in approaches to supporting commercialization, attracting foreign investment, and encouraging international partnerships in the R&D sphere. *Conceptual* PL has also been actively applied in Indonesia and the Philippines [*Damuri et al.,* 2018; *Quimba et al.,* 2018].

PL was most actively carried out by the RTTG and officials at different levels. A similar situation was observed in Thailand, where the National Science, Technology, and Innovation Committee (NSTIC) and the National Research Council (NRC) made key contributions to the development of innovation policy [UNCTAD, 2015].

The role of experts is increasing: they participated in PL for eight of the 16 objectives under consideration. As to the PL mechanisms, the most common ones are learning from past experience and evaluating the implementation of previous plans (applied in 11 and 12 cases, respectively). This means that R&D policy in Iran is increasingly shaped using a scientific, evidence-based approach. Given the growing involvement in PL of various kinds of actors, primarily experts, establishing a dialogue between them is becoming increasingly important.

Conclusion

This paper presents a case study of the practical application of PL in shaping Iran's science, technology, and innovation policy. Based on the survey results and strategy analysis, different policy learning types and mechanisms have been identified. The findings can be useful for shaping appropriate policies in other countries, primarily developing ones.

1. To accomplish real shifts and increase the effectiveness of innovation policy, technical, conceptual, and social PL should be used, while keeping the use of partisan PL to a minimum. This would be possible only if a wide range of stakeholders are involved in policy shaping, with a sufficiently deep dialogue between them. The economic effect will be achieved if innovation development is consistent with other policy areas (educational, industrial, policies and so on).

2. Pragmatic short- and medium-term goals should be set, for example, to increase businesses' contribution to R&D by introducing relevant incentives.

3. PL procedures should be improved upon by experimenting with the innovation system in line with evidence-based principles. Not only formal quantitative indicators should be taken into account (e.g., the export of new products), but also its contribution to economic growth [*Albert et al.,* 2013]. Policy evaluation allows one to determine whether the goals and the tools applied to achieve them were adequate [*Dawkins, Colebatch,* 2006]. Regular foresight studies can provide informational context, describing the mainstream and emerging technology landscape.

4. Previous results must be evaluated prior to developing new strategies; a limited number of basic issues should be identified to focus on.

5. The importance of emerging windows of opportunity for the R&D sphere should be demonstrated to the government in a sufficiently clear way [*Lee,* 2005]. Gaining political support for making use of such windows will help build up the technological potential in the short or medium term already.

6. An efficient transition to the knowledge economy would not be possible without the involvement of politicians. To form such a commitment, the potential contribution of R&D to accomplishing various economic, social, and environmental objectives should be demonstrated [*Mazzucato,* 2021].

Other important factors contributing to the increased maturity and stability of the innovation system are introducing effective mechanisms to protect domestic high-technology markets, promoting demand for relevant products, and involving businesses in policy-making and the creation of development institutions.

References

Albert N., Link N., Vonortas N. (2013) *Handbook on the Theory and Practice of Program valuation*, Cheltenham: Edward Elgar Pub.

Argote L. (2012) *Organizational learning: Creating, retaining and transferring knowledge*, Berlin: Springer Science & Business Media Pub.

Bailey I., Compston H. (2010) Geography and the politics of climate policy. *Geography Compass*, 8(4), 1097–1114. http://dx.doi.org/10.1111/j.1749-8198.2010.00366.x

Baldwin G.B. (1967) *Planning and development in Iran*, Baltimore: Johns Hopkins Press.

Bennett C.J., Howlett M. (1992) The lessons of learning: Reconciling theories of policy learning and policy change. *Policy Sciences*, 25(3), 275–294. http://dx.doi.org/10.1007/BF00138786

Biegelbauer P. (2016) How different forms of policy learning influence each other: Case studies from Austrian innovation policy-making. *Policy Studies*, 37(2), 129–146. http://dx.doi.org/10.1080/01442872.2015.1118027

Boekholt P. (2010) The Evolution of Innovation Paradigms and their Influence on Research, Technological Development and Innovation Policy Instruments. In: *The Theory and Practice of Innovation Policy* (eds. R.E. Smits, S. Kuhlmann, P. Shapira), Cheltenham: Edward Elgar Pub., pp. 333–362.

Borrás S. (2011) Policy learning and organizational capacities in innovation policies. *Science and Public Policy*, 38(9), 725–734. http://dx.doi.org/10.3152/030234211X13070021633323

Bostock F., Jones G. (2014) *Planning and Power in Iran: Ebtehaj and Economic Development Under the Shah*, London: Routledge Pub.

Braun D., Benninghoff M. (2003) Policy learning in Swiss research policy — The case of the National Centres of Competence in Research. *Research Policy*, 32(10), 1849–1863. http://dx.doi.org/10.1016/S0048-7333(03)00063-5

Casady C.B., Parra J.D. (2020) Structural Impediments to Policy Learning: Lessons from Colombia's Road Concession Programs. *International Journal of Public Administration*, 44(5), 359–371. http://dx.doi.org/10.1080/01900692.2020.1724142

Damuri Y., Aswicahyono H., Christian D. (2018) Innovation Policy in Indonesia. In: *Innovation Policy in ASEAN* (ed. M. Ambashi), Jakarta: Economic Research Institute for ASEAN and East Asia, pp. 96–127. https://www.eria.org/uploads/media/5.ERIA_Innovation_Policy_ASEAN_Chapter_4.pdf, accessed 18.06.2021

Dawkins J., Colebatch H.K. (2006) Governing through Institutionalized Networks: The Governance of Sydney Harbour. *Land Use Policy*, 23 (3), 333–343. http://dx.doi.org/10.1016/j.landusepol.2004.09.006

Dunlop C.A. (2017) Pathologies of policy learning: What are they and how do they contribute to policy failure? *Policy and Politics*, 45(1), 19–37. http://dx.doi.org/10.1332/030557316X14780920269183

Dunlop C.A., Radaelli C.M. (2013) Systematizing policy learning: From monolith to dimensions. *Political Studies*, 61: 599–619. http://dx.doi.org/10.1111/j.1467-9248.2012.00982.x

Dutta S., Lanvin B., Wunsch-Vincent S. (2020) *The Global Innovation Index 2020: Who Will Finance Innovation?*, Ithaca, Fontainebleau, Geneva: WIPO. https://www.wipo.int/edocs/pubdocs/en/wipo_pub_gii_2020.pdf, accessed 15.07.2021.

Fartash K., Khayatian M., Ghorbani A., Sadabadi A. (2021) Interpretive Structural Analysis of Interrelationships of the Sustainable Development Goals (SDGs) in Iran. *International Journal of Sustainable Development and Planning*, 16(1), 155–163. http://dx.doi.org/10.18280/ijsdp.160116

Fiorino D. (2001) Environmental policy as learning: A new view of an old landscape. *Public Administration Review*, 61(3), 322–334. http://dx.doi.org/10.1111/0033-3352.00033

Freeman C. (1987) *Technology policy and economic policy: Lessons from Japan*, London: Frances Pinter.

Gaillard J. (2010) Science and Technology in Lebanon: A University-driven Activity. *Science, Technology and Society*, 15(2), 271–307. http://dx.doi.org/10.1177%2F097172181001500205

Hall P.A. (1993) Policy Paradigms, Social Learning and the State: The Case of Economic Policymaking in Britain. *Comparative Politics*, 25 (3), 275–296. http://dx.doi.org/10.2307/422246

Heclo H. (1974) *Modern Social Politics in Britain and Sweden*, New Haven CT: Yale University Press.

Heshmati A., Dibaji S.M. (2019) Science, Technology, and Innovation Status in Iran: Main Challenges. *Science, Technology and Society*, 24(3), 545–578. http://dx.doi.org/10.1177/0971721819873192

Johnson B.H. (2010) Institutional learning. In: *National systems of innovation: Toward a theory of innovation and interactive learning* (ed. B.Å. Lundvall), London: Anthem Press, pp. 23–46.

Kim L. (1997) *Imitation to innovation: The dynamics of Korea's technological learning*, Cambridge, MA: Harvard Business Press.

Klochikhin E.A. (2013) Innovation system in transition: Opportunities for policy learning between China and Russia. *Science and Public Policy*, 40 (5), 657–673. http://dx.doi.org/10.1093/scipol/sct021

Lee K. (2005) Making a Technological Catch-up: Barriers and opportunities. *Asian Journal of Technology Innovation*, 13(2), 97–131. http://dx.doi.org/10.1080/19761597.2005.9668610

Lieu J. (2013) *Influences of policy learning, transfer, and post transfer learning in the development of China's wind power policies*, Brighton: University of Sussex.

Lim H. (2018) Innovation Policy in Singapore. In: *Innovation Policy in ASEAN* (ed. M. Ambashi), Jakarta: Economic Research Institute for ASEAN and East Asia, pp. 198–217. https://www.eria.org/uploads/media/8.ERIA_Innovation_Policy_ASEAN_Chapter_7.pdf, accessed 12.06.2021.

May P.J. (1992) Policy Learning and Failure. *Journal of Public Policy*, 12 (4), 331–354. http://dx.doi.org/10.1017/S0143814X00005602

Mazzucato M. (2021) *Mission Economy: A Moonshot Guide to Changing Capitalism*, Dutton: Penguin Pub.

McCann E., Ward K. (2012) Policy assemblages, mobilities and mutations: Toward a multidisciplinary conversation. *Political Studies Review*, 10(3), 325–332. http://dx.doi.org/10.1111/j.1478-9302.2012.00276.x

McKinsey & Company (2016) *Iran: A 'trillion-dollar opportunity?,* New York: McKinsey Global Institute. https://en.inif.ir/documents/40462/302234/2016.pdf/8e6dafac-e6c8-5800-b6c4-b3f967c3a953?t=1577084952000, accessed 08.04.2021.

McLeod T.H. (1964) *National Planning in Iran: A report based on the experiences of the Harvard Advisory Group in Iran*, Cambridge, MA: Harvard Advisory Group.

Moyson S., Scholten P., Weible C.M. (2017) Policy learning and policy change: Theorizing their relations from different perspectives. *Policy and Society*, 36(2), 161–177. http://dx.doi.org/10.1080/14494035.2017.1331879

Murrall-Smith S. (2011) *Policy learning and the development of renewable energy policy in the United Kingdom*, Plymouth: University of Plymouth.

Narayanan H., Yew-Wah L. (2018) *Innovation Policy in Malaysia*. In: *Innovation Policy in ASEAN* (ed. M. Ambashi), Jakarta: Economic Research Institute for ASEAN and East Asia, pp. 128–162. https://www.eria.org/uploads/media/6.ERIA_Innovation_Policy_ASEAN_Chapter_5.pdf, accessed 04.11.2020.

Nelson R.R., Winter S.G. (1982) *An evolutionary theory of economic change*, Cambridge, MA: Harvard Business Press.

Nilsson M. (2005) Learning, frames, and environmental policy integration: The case of Swedish energy policy. *Environment and Planning C: Government and Policy*, 23(2), 207–226. http://dx.doi.org/10.1068/c0405j

Oladeji S.I., Adegboye A.A. (2019) Science and Technology Policy for Nigeria's Development Planning. *Journal of Education, Society and Behavioural Science*, 32(4), 1–12. http://dx.doi.org/10.9734/jesbs/2019/v32i430182

Oliver M.P., Pemberton H. (2004) Learning and change in 20th century British economic policy. *Governance*, 17, 415–441. http://dx.doi.org/10.1111/j.0952-1895.2004.00252.x

Penrose E.T. (1959) *The Theory of the Growth of the Firm*, Oxford: Oxford University Press.

Quimba F.M., Albert J.R., Llanto G.M. (2018) *Innovation Policy in Philippines*. In: *Innovation Policy in ASEAN* (ed. M. Ambashi), Jakarta: Economic Research Institute for ASEAN and East Asia, pp. 163–197. https://www.eria.org/uploads/media/7.ERIA_Innovation_Policy_ASEAN_Chapter_6.pdf, accessed 17.03.2021.

Rietig K., Perkins R. (2017) Does learning matter for policy outcomes? The case of integrating climate finance into the EU budget. *Journal of European Public Policy*, 25(4), 487–505. http://dx.doi.org/10.1080/13501763.2016.1270345

Rongping M., Zhongbao R., Sida Y., Yan Q. (2008) Technology foresight towards 2020 in China: The practice and its impacts. *Technology Analysis & Strategic Management*, 20(3), 287–307. http://dx.doi.org/10.1080/09537320801999587

Sabatier P.A. (1988) An Advocacy Coalition Framework of Policy Change and the Role of Policy-Oriented Learning Therein. *Policy Sciences,* 21: 129–168. http://dx.doi.org/10.1007/BF00136406

Salisu Y., Bakar L. (2019) Technological capability, relational capability and firms' performance the role of learning capability. *Revista de Gestão*, 27(1), 79–99. http://dx.doi.org/10.1108/REGE-03-2019-0040

Sanderson I. (2002). Evaluation, Policy Learning and Evidence-Based Policy Making, *Public Administration*, 80 (1), 1–22. http://dx.doi.org/10.1111/1467-9299.00292

Schoemaker P.J.H. (2020) How historical analysis can enrich scenario planning. *Futures and Foresight Science*, 2(3-4), e35. https://doi.org/10.1002/ffo2.35

Schwerin J., Werker C. (2003) Learning innovation policy based on historical experience. *Structural Change and Economic Dynamics*, 14(4), 385–404. http://dx.doi.org/10.1016/S0954-349X(03)00031-6

Sharabaroff A., Stuggins G., Semikolenova Y. (2013) *Energy Efficiency: Lessons Learned from Success Stories*, Washington: World Bank Publications.

Siyanbola W., Adeyeye A., Olaopa O., Hassan O. (2016) Science, technology and innovation indicators in policy-making: The Nigerian experience. *Palgrave Communications*, 2, 16015. http://dx.doi.org/10.1057/palcomms.2016.15

Smits R., Kuhlmann S. (2004) The rise of systemic instruments in innovation policy. *International Journal of Foresight and Innovation Policy*, 1(1–2), 4–32. http://dx.doi.org/10.1504/IJFIP.2004.004621

Soofi A., Ghazinoory S. (2013) *Science and Innovations in Iran: Development, Progress, and Challenges*, London: Palgrave Macmillan Pub.

Souzanchi Kashani E. (2020) Linking institutions and technical changes in a developing context: Historical evidence from Iran. *Innovation and Development*, 10(3), 347–371. http://dx.doi.org/10.1080/2157930X.2019.1647614

Suurs R., Hekkert M., Kieboom S., Smits R. (2010) Understanding the formative stage of technological innovation system development: The case of natural gas as an automotive fuel. *Energy Policy*, 38, 419–431. http://dx.doi.org/10.1016/j.enpol.2009.09.032

UNCTAD (2015) *Science, Technology and Innovation Policy Review of Thailand*, Geneva: United Nations Conference on Trade and Development. https://unctad.org/system/files/official-document/dtlstict2015d1_en.pdf, accessed 16.07.2021

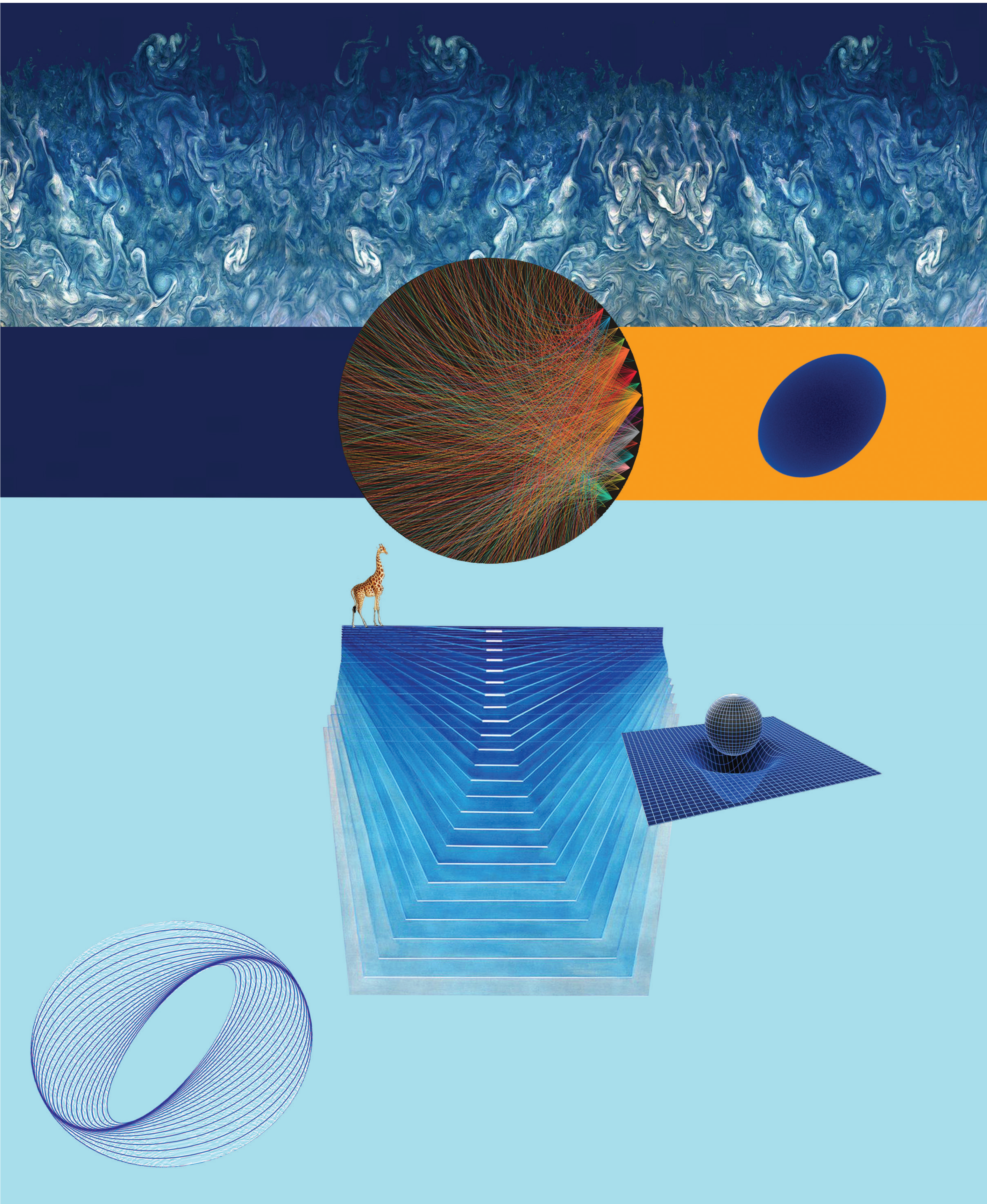
UNCTAD (2016) *Science, Technology and Innovation Policy Review of the Islamic Republic of Iran*, Geneva: United Nations Conference on Trade and Development. https://unctad.org/system/files/official-document/dtlstict20163_en.pdf, accessed 16.07.2021

UNESCO (2008) *Science, Technology & Innovation Policy for Lebanon: Comprehensive Document*, Paris: The United Nations Educational, Scientific and Cultural Organization. http://www.unesco.org/new/fileadmin/MULTIMEDIA/HQ/SC/pdf/sc_sti_lebanon_en.pdf, accessed 12.02.2021.

Yin R.K. (2013) *Case study research: Design and methods*, California: Sage Pub.

Yongabo P., Göransson B. (2020) Constructing the national innovation system in Rwanda: Efforts and challenges. *Innovation and Development*, http://dx.doi.org/10.1080/2157930X.2020.1846886

Zhang Y., Marsh D. (2016) Learning by doing: The case of administrative policy transfer in China. *Policy Studies*, 37(1), 35–52. http://dx.doi.org/10.1080/01442872.2015.1107959



Multi-Framework Implementation of the Problem Management Process

Ruben Pereira

Assistant Professor, ruben.filipe.pereira@iscte-iul.pt

Instituto Universitário de Lisboa (ISCTE-IUL), Avenida das Forças Armadas, 1649-026 Lisbon, Portugal

Isaías Scalabrin Bianchi

External Researcher, isaias.bianchi@gmail.com

Institute of Scientific Research, Universidad de LimaAv. Javier Prado Este 4600, Santiago de Surco 15023, Lima, Peru

Virgínia Maria da Silva Araújo

Assistant Professor, varaujo@uatlantica.pt

Atlantica University, School of Management Sciences, Health, IT & Engineering, Fábrica da Pólvora de Barcarena, 2730-036 Barcarena, Portugal

Abstract

Many different information technology frameworks have been proposed to assist organizations implementing information technology. However, these frameworks are complex, difficult to implement, and overlap with one another making their simultaneous implementation even more difficult to accomplish by organizations. This study proposes to develop an overlap-less maturity model that helps organizations deal with the aforementioned problems. The model was applied and evaluated by experts at five organizations. This approach was recognized as useful, complete, and helpful in a multi-framework implementation by problem management (PM) experts. This research provides contributions for academics since it distinguishes itself from the existing studies in the body of knowledge and is a baseline for further investigation.

Keywords: IT frameworks; problem management; Maturity model; multi-framework implementation; frameworks overlap

Citation: Pereira R., Bianchi I.S., da Silva Araújo V.M. (2021) Multi-Framework Implementation of the Problem Management Process. *Foresight and STI Governance*, 15(3), 94–104. DOI: 10.17323/2500-2597.2021.3.94.104

Introduction

Since the 1980s organizations have sought out competitive advantage and have become more cost-effective through the achievement of operational improvements [*Kappelman et al.,* 2019]. The presence of computer and information technology (IT) in today's organizations has expanded dramatically [*Carvalho et al.,* 2019a; *Patón-Romero et al.,* 2018] and has pushed IT functions to become more service-oriented to be more cost-effective and aligned with business objectives [*Carvalho et al.,* 2019b; *Tan et al.,* 2010]. Nowadays, most organizations are deeply dependent upon IT in order to plan, design, deliver, operate, and control IT services offered to customers. IT departments are actually one of the most complex parts of an organization [*Ayat et al.,* 2009]. To deal with the increase of IT complexity, many IT frameworks have been developed and proposed. All these frameworks have value to offer along with different strengths and weaknesses [*Aguiar et al.,* 2018]. For example, the IT Infrastructure Library (ITIL) [*Long,* 2008], Control Objectives for Information and Related Technologies (COBIT) [ISACA, 2012], and Capability Maturity Model Integration for Services (CMMI-SVC) [SEI, 2010] are among the most popular ones.

Over the years, organizations have focused heavily on improving their IT processes to be able to bring remarkable benefits. One of the ways to improve IT processes is using IT frameworks and many organizations use them. Some researchers have reported the benefits of these frameworks [*Huygh et al.,* 2018].

However, not only are IT frameworks seen as complex [*Serenko et al.,* 2016], but the lack of assistance for customizing and implementing such frameworks make it difficult for organizations to choose one since it is unclear which IT framework better suits established IT environments [*de Haes, van Grembergen,* 2017]. Often the processes end by not being consistent and properly defined [*Rohloff,* 2008]. Plus, most of these IT frameworks overlap each other [*de Haes et al.,* 2013]. This implies the duplication of investment, costs, and human resources for organizations [*Gama et al.,* 2013]. However, they can be combined to narrow the gaps and then become more powerful than individual systems [*Aguiar et al.,* 2018].

As pointed out by several authors such as [*Aguiar et al.,* 2018; *Schlarman,* 2007] IT frameworks can easily overlap one another. Moreover, IT frameworks are complex to understand and implement [*de Haes et al.,* 2013; *Evelina et al.,* 2010; *Herrera, Hillegersberg,* 2019; *Serenko et al.,* 2016].

By way of response, the maturity model (MM) concept was introduced to assess the level of a process [*Becker et al.,* 2009]. Process MMs are being implemented by an increasing number of organizations [*Uskarc, Demirörs,* 2017] because they lay the groundwork as a measure to evaluate an organization's capabilities in a specific discipline [*de Bruin et al.,* 2005]. As pointed out by [*Becker et al.,* 2009], most MMs are considered too general and are usually not clearly defined and documented. Moreover, the current MMs do not address the overlap issue identified by several research studies [*Sahibudin et al.,* 2008]. Among the most important processes proposed by IT frameworks is Problem Management (PM). However, implementing the PM process properly can be complex, long, expensive, and may cause PM implementation to fail [*Sharifi et al.,* 2009; *Pereira et al.,* 2012] leading to low quality service delivery. This means that PM can shape how customers see the entire organization and impact business considerably. Despite the popularity of some IT frameworks, there has been little academic research published to date about issues related to maturity model adoption and implementation [*Cater-Steel et al.,* 2006; *Jansen,* 2020].

In accordance with the statements mentioned above, this study aims to develop an overlap-less and complete IT MM for the PM process grounded in ITIL, COBIT, and CMMI-SVC content following the theory proposed by [*Becker et al.,* 2009] (which is based on the Design Science Research (DSR) methodology [*Gregor, Hevner,* 2013]).

Theoretical Background

IT Frameworks

The literature describes many IT frameworks, which are also called best practices and standard guidelines that assist the organization in the management of its technology infrastructure. The most relevant guidelines with the majority of citations are ITIL, COBIT and CMMI-SVC [*Pereira, Mira da Silva,* 2012].

ITIL is a set of best practices [*Long,* 2008] and one of the world's most widely accepted approaches to ITSM [*Saarelainen, Jantti,* 2016]. ITIL necessitates cultural changes and usually requires the use of specialists to enact and adapt it to each organizational context [*Bovim et al.,* 2014]. The ITIL framework has been adopted by companies of all sizes and industries, including large, medium, and small businesses.

COBIT is an IT framework for designing, adopting, tracking, and optimizing IT governance and management procedures. It is one of the most widely used in the world. Its processes are divided into governance and management areas.

Finally, the CMMI-SVC [SEI, 2010] not only defines IT procedures but also a set of practices and goals that companies can use to implement their own sets of processes. A particular objective, according to the CMMI framework, defines the unique features that must be present to meet the process requirements. A specific practice is a description of an activity that is thought to be critical in achieving the associated goal [*Aguiar et al.,* 2018]. Plus, this section also intends to present a brief analysis of each IT framework (Table 1). Since the PM process is included in each framework, it makes them suitable IT frameworks upon which to ground our proposal.

IT Maturity Models

There is a consensus in the literature regarding the efficiency of MMs (Table 2). MMs depict a hierarchy of maturity levels for a certain class of objects (typically organizations or processes [*Becker et al.,* 2009]) and the expected, required, or typical evolution paths of these objects in the form of discrete stages. This format allows for evaluating the applied processes through the prism of best management experience and a set of external parameters.

The initial work from AXELOS to measure service management processes started with the Process Maturity Framework (PMF) which was published and made available as an appendix of the ITIL "Service Design" publication [*Long,* 2008]. This PMF is used as a framework to evaluate the maturity of each of the Service Management processes independently or to measure the maturity of the overall Service Management process. [*Long,* 2008]. An updated model named "ITIL Maturity Model" presumes a self-assessment service to help organizations improve their IT service management within the ITIL framework [*Aguiar et al.,* 2018]. This self-assessment is based on a series of questionnaires for each process and function in the ITIL service lifecycle.[1]

Following the research conducted by [*Aguiar et al.,* 2018] as a reference, Tables 2 and 3 provide a short summary of the previously mentioned IT MMs so that readers can better understand how these MMs differ from one another. Almost all of the compared MMs have five levels. Two of them base their theories on ISO/IEC 15504. The most intriguing fact is that each of the identified MMs takes a unique approach, focusing solely on their own theory. It should be observed that none of these MMs address the problem of IT framework overlap.

One of the main advantages of the proposed approach is that the person doing the evaluation does not need to be an IT governance specialist because the analysis is done automatically [*Simonsson et al.,* 2007]. The modeling language is based on COBIT and provides for the identification of entities and relations. The entities identified were: activities, KPI/KGI processes, documents, and roles [*Aguiar et al.,* 2018]. Pereira and Mira da Silva [*Pereira, Mira da Silva,* 2010, 2011] proposed a model that is also based on CMMI-SVC. This MM was distinguished among others on the market at the time because it was designed exclusively to assist businesses in measuring their ITIL v3 maturity and leading them through the implementation of ITIL. The proposed IT Service Delivery MM, on the other hand, was a mechanism for formalizing and assessing IT Service Delivery Elements [*Flores et al.,* 2011]. The authors of the aforementioned study established five levels of maturity, similar to CMMI-SVC. The adopted scale to score the maturity level is 1 to 5. To better distinguish between maturity states, the authors add a "+" or a "-" whether the level is closer to being up or down. Vitoriano and Neto [*Vitoriano, Neto,* 2016] used a methodology based on the Process Maturity Framework (PMF), an MM defined in the ITIL (v2) reference model. To use this MM, some interviews with questions related to the five maturity levels, such as initial, repetitive, defined, managed, and optimized, are required; information was gathered on five fundamental ITSM processes.

More recently Aguiar et al. [*Aguiar et al.,* 2018] developed a MM for the incident management (IM) process where the overlap issue was addressed and mitigated. The authors also took into consideration the main IT frameworks on the market. The results were exciting with great feedback from the experts. The study found that the main IT frameworks overlap each other almost 25% regarding the IM process.

After analyzing the main IT frameworks and MMs among the literature, the authors were able reinforce the theory that most MMs ground their development on CMMI. Moreover, only one of the analyzed MMs take into consideration the overlap issue. It is the most recent study [*Aguiar et al.,* 2018] where the researchers developed a MM for the IM process and incentivized future researchers to develop overlap-less MMs for the remaining IT processes. Therefore, such findings strengthen the aim and relevance of this research. It can be observed that the inquiry into the implementation of multi-frameworks and how it can be handled and measured has been financially rewarded [*de Haes et al.,* 2013].

Research Methodology

Recently, Design Science Research (DSR) has gained importance and popularity in information systems. Many researchers have used DSR to develop an innovative approach in order to solve a specific and relevant organizational problem domain [*Hevner et al.,* 2004]. The adopted research methodology was the DSR which has been incentivized to be used in a myriad of fields [*Rai,* 2017] including IT governance, covering a broad range of IT-related processes [*Gregor, Hevner,* 2013; *de Maere, de Haes,* 2017]. The key elements of DSR under investigation are the possibilities of discovering new fields of research, conducting testing and the validation of theories or building new theories. The purpose of this work is to to develop an overlap-less maturity model to solve a specific problem and help the organizatons. Therefore, DSR can be a suitable approach for this study. The proposed method was designed and evaluated following Peffers guidelines [*Peffers et al.,* 2007] as you can see in the Figure 1.

Proposal of an Overlap-less Maturity Model

For the development of MMs, Becker et al. [*Becker et al.,* 2009] identified a set of necessary requirements with which our proposal strictly complies (Table 4). In

[1] https://docplayer.net/655929-Itil-maturity-model-october-2013.html, accessed 15.07.2021.

Table 1. **Comparing IT Frameworks**

Model	ITIL V3	COBIT 5	CMMI-SVC
Founder	OGC	ISACA, ITGI	Software Engineering Institute (SEI)
Focus	IT Service	IT Service	IT Service
PM	Yes	Yes	Yes
Name of Process	Problem Management	Manage Problems	Causal Analysis and Resolution
Number of Processes	26	37	24
Source: authors.			

addition, the development of the proposed PM MM was accomplished by following three steps: (1) Elicitation of PM activities from the most well-known IT frameworks; (2) Elimination of overlaps; and (3) definition of the maturity level for each elicited activity.

Phase 1: The first step focused on identifying all of the PM activities present in the ITIL, CMMI-SVC, and COBIT frameworks, as well as specifically identifying the IT frameworks supporting each elicited activity (Table 5). At the end of this phase, 349 activities had been gathered (Table 6). Table 7 shows a sample of its activities. The authors went through four iterations of fine-tuning the list to reach at a final consensus list.

Phase 2: The authors using the initial list concluded the phase (*ant-overlap*), moved on to the next, which involved a thorough identification of IT framework overlaps. During this phase, all activities were separated by process areas to make identifying overlaps easier. To demonstrate the outcome of this step, the authors present Table 7, which explains how the overlap elimination was carried out. By the end of this phase, 46 PM activities had been identified as overlapping among the selected IT frameworks. This accounts for 13% of the initial set of activities gathered. It was possible to create a new list (post-overlap) of activities with 303 activities by merging activities and eliminating overlaps (Table 7).

Finally, to complete the proposal, the authors organized the final set of activities by maturity level. The maturity levels were assigned based on the adherence of each activity to the CMMI-SVC description of maturity levels.

Using the same activities as in Table 5, the authors present Table 7 to illustrate how the maturity levels were assigned to each activity.

As an example, only one activity sample was provided for each existing maturity level. Here, the authors decided to follow the maturity level definitions of CMMI-SVC since they are used in the development of most MMs present in the literature. An activity classified as level 2 is considered a basic activity in the PM process since it is the first step for information collection. An activity classified as level 3 is mostly included among standards, procedures, or methods. An activity ranked as level 4 is focused on process measurement; such are usually metrics aimed at measuring a specific process aspect. Finally, an activity classified as level 5 is focused on the continuous improvement of processes and all activities involved in pursuing this kind of activity type. During the semi-structured interviews, a questionnaire was provided that consisted of all collected post-overlap activities, arranged by order of process (problem identification, problem logging, etc.), in order to become rational and concise throughout its course.

It should be stated that this approach only focuses on the framework activities. There are other relevant concepts (for example inputs, outputs, metrics, etc.) that organizations must still collect from the IT frameworks. However, by using our method first, organizations will have a clear vision of the core activities and the respective frameworks that they can then check later for further information. This does not substitute the IT frameworks. It may be seen as a complement to guiding organizations in further steps.

Demonstration and Evaluation

In order to demonstrate the proposed approach, the authors have searched for organizations with PM processes in place (up and running) and invited them to participate. Five organizations accepted the invitation to be assessed by the authors and to evaluate the proposed method. Both demonstration and evaluation were performed through semi-structured interviews

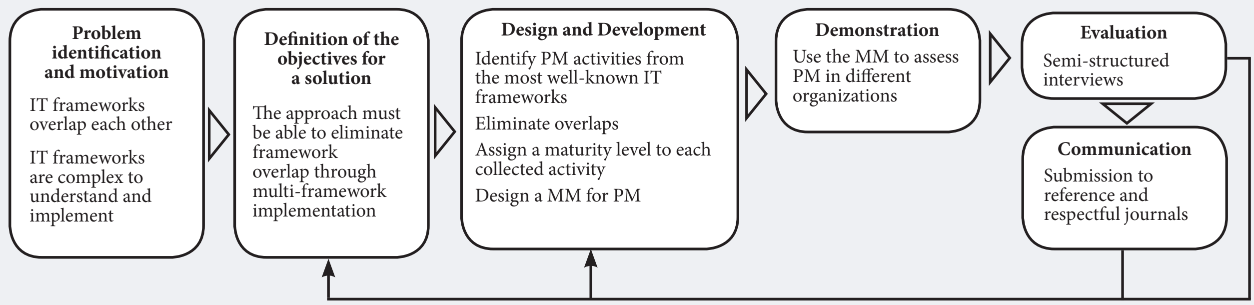
Table 2. **Comparison of Frameworks' MMs**

Model	COBIT PAM	CMMI-SVC	AXELOS
Number of levels	0-5	SM:1-5	1-5
Scope	Governance	CM:0-5	IT Services
Based on	ISO/IEC 15504	IT Services	—
Approach	Individual	—	Individual
Frameworks overlap	Not addressed	Individual	Not addressed
Source: authors.			

Table 3. **Comparison of MM Levels**

Level	COBIT PAM	CMMI-SVC	AXELOS
0	Incomplete	—	—
1	Performed	Initial	Initial
2	Managed	Managed	Repeatable
3	Established	Defined	Defined
4	Predictable	Quantitatively Managed	Managed
5	Optimizing	Optimizing	Optimizing
6	—	—	—
Source: authors.			

Figure 1. **DSR Phases**



Source: adapted from [*Peffers et al.,* 2007].

with experts from the respective organizations. In particular, the authors interviewed the PM process owner of each organization. During each interview, the list (post-overlap) was presented to the interviewee so he could confirm whether each activity had been implemented or not. The maturity level of each activity was not presented to avoid biased answers. At the end, the individual and global reports were sent to the interviewee. Any person/organization intending to apply the approach in the future should perform it in the same way.

Data Collection and Analysis

The interviews were conducted in different organizational contexts and with the most suitable decision-makers to assess and provide information about the PM process. Details about the interviewees can be found in Table 8.

The interviews were conducted between March and July of 2018. In a total of five interviews (two via Skype and three in person). The average time required for each interview was one hour and 45 minutes. To prepare and help the interviewees before the assessment, a questionnaire was developed and delivered a few days before the interview. The questionnaire to frame the interview was developed in three parts. The first part contained general questions about the organization and the profile of interviewee. The second delved into the implementation of the activities. Finally the third part posed questions about the points of view and opinions of the interviewee regarding the PM MM.

In Table 9 one can see organization's details. Organizational culture was described based on the theory proposed by [*Matthyssens, Wursten,* 2002].

Overall the assessed organizations have at least 1,400 employees and considerable IT departments. Some organizations did not permit the publication of some information. None of the assessed organizations had any sense of their maturity level. Such evidence brings even more relevance to this study.

According to [*Pereira, Mira da Silva,* 2012], in order to achieve a maturity level, organizations had to imple-

Table 4. **How the Proposed Approach Complies with the Becker Requirements**

Requirement	Description
Comparison with existing MMs	A comparison between IT frameworks should be made, mainly focusing on the most well-known and those relevant for the case.
Iterative procedure	The identification of the first list of activities (1) was achieved through an iterative process. Plus, interviews can be considered an interaction due the continuous feedback received from practitioners in order to improve this process.
Evaluation	For the assessment of the approach, five semi-structured interviews were performed keeping in mind the interactive process used in all interviews.
Multi-methodological procedure	Several methodologies were used for the creation of the model: literature review, cross frameworks analysis, and semi-structure interviews. Plus, this research fulfills DSR procedures and Becker requirements.
Problem definition	There is no limitation in the application of the proposed PM MM unless PM practices already exist at the target organization. It can be applied at any organization regardless of the classification presented in [*Pereira et al.,* 2013]. The main expected benefit is the prior identification of overlapping activities that may save resources in future implementations of multi-frameworks.
Interim monitoring and target presentation of results	Based on results collected throughout the assessment of the approach, it is possible to provide two types of reports: an individual report for each organization and a global/cross-organization report. The individual report can provide information regarding the current organizational maturity level and a maturity roadmap including the required steps to reach the next level. Information can also be found about achieved activities and the identification of which framework complies best as well as missing activities identified in the roadmap. By using the roadmap, organizations are able to become more efficient at saving resources in future multi-framework implementations. The global report is achievable by combining and cross-referencing all information received from each assessment.

Source: authors.

Table 5. **Sample of Pre-Overlap Activities among IT Frameworks**

Activity	IT Framework
Has the defect or problem been identified?	COBIT
Has a problem record been raised? If yes, does the problem contain all relevant details?	ITIL
After the problem is identified, do you usually develop a suitable workaround?	CMMI-SVC
Do you usually analyze the change in process performance of the affected processes or sub-processes for the work? If yes, do you measure it?	COBIT
Are the lessons learned from the review presented at a service review meeting with the business customer?	ITIL
Do you usually try to find a workaround to temporarily solve the problem?	ITIL
Has the problem been identified?	CMMI-SVC

Source: authors.

ment at least 75% of the activities of that corresponding level. Based on Figure 2, one can see level 2 is the most mature among the assessed organizations, followed by level 3, level 4, and level 5, respectively. Overall organizations are more focused on definition and management activities but neglect metrics and measures to promote continuous improvement and predictive analysis.

An individual analysis is presented in Figure 3. All organizations have a similar maturity level, generally at level 2 (Managed). Level 5 (optimizing) is the lowest level, followed by level 4 (Quantitatively Managed) and finally level 3 (defined). Apparently, there is no visible disparity between the various types of organizations.

Despite the authors' conviction, none of the assessed organizations met the conditions to reach level 2 (75%). The telecommunications company is the nearest one to achieve it. All organizations are at level 1 (initial). On average, the organizations tended to focus their efforts toward the first two levels, level 2 and 3. To be considered a managed process (level 2) and reach level 3 (defined), most organizations would need to implement between 12% and 37% of the remaining activities. For some, it may be a considerable effort.

Table 6. **PM Activity Results after Applying the First Two Steps**

Model	PM process name	Number of activities (nº)	Percentage (%)
ITIL	*Problem Management*	153	44
COBIT	*Manage Problems*	85	24
CMMI-SVC	*Causal Analysis and Resolution*	111	32
Ant-Overlap activities		349	100
Overlapped activities		46	13
Post-Overlap activities		303	87

Source: authors.

Overall, the software organization seems to be the least mature and the bank seems to be the most mature. The assessed bank is the only one with a similar percentage for levels 2 and 3. All the other organizations have a considerable higher percentage of level 2. The telecommunications company achieved the highest percentage for level 2 but falls about 20% when considering level 3 while the bank has a more stable and balanced percentage among the first two levels.

Another interesting finding is that, apparently, organizations are aligned with MM theory. According to the MM theory, a previous level is crucial for achieving the next level. This means that it would not make sense, for example, to have a higher percentage of level 3 than level 2. Based on that, the authors may argue that organizations are aligned with these guidelines. None of the organizations have a maturity level with higher percentage than the previous one. Such a fact indicates that despite none of the assessed organizations being at level 2, they are implementing the process in a coordinated and balanced way.

Additional insights can be obtained regarding the IT frameworks adopted within each organization. Most of the interviewed organizations (80%) pointed to ITIL as the officially adopted IT framework with the last organization adopting CMMI-SVC (20%). Such a finding is aligned with previous studies claiming that ITIL was one of the most adopted IT frameworks on the market [*Long,* 2008; *Saarelainen, Jantti,* 2016]. Plus, the authors also found that ITIL activities are the most implemented in number and percentage. Table 10 illustrates all the insights gathered from the assessments regarding the adoption of each IT framework.

Evaluation

After completing the interview process, the interviewees were invited to provide some feedback by answering some questions in order to evaluate the approach and consequently the problem statement of our research. As illustrated in Table 11, from a global perspective, the opinion was positive. Some interviewees mentioned that it was exhaustive but complete which is quite understandable. However, it was agreed upon among the interviewees that the proposed method is useful in providing a complete vision of the PM process based on the three most-known IT frameworks. No activity was considered absent, which validates the first (1) and second (2) steps performed to develop the approach.

Discussion

Despite the existence of several IT frameworks to help organizations increase IT efficiency, such are seen as complex [*Serenko et al.,* 2016], difficult to implement [*de Haes, van Grembergen,* 2017], prone to overlap one another [*Schlarman,* 2007; *Pereira, Mira da Silva,* 2011],

Table 7. **Demonstration of the Merging Process**

Activity	Maturity Level	ITIL	CMMI-SVC	COBIT
Are the problems identified?	2	Has a problem record been raised?	Has the defect or problem been identified?	Has the problem been identified?
Do you usually try to find a workaround to solve the problem?	3	Do you usually try to find a workaround to temporarily solve the problem?	-	After the problem is identified, do you usually develop a suitable workaround?
Do you usually analyze the change in the performance of the affected processes or sub-processes for the work? If yes, do you measure it?	4	-	Do you usually analyze the change in the performance of the affected processes or sub-processes for the work? If yes, do you measure it?	—
Are the lessons learned from the review presented during a service review meeting with the business customer?	5	Are the lessons learned from the review is presented during a service review meeting with the business customer?	-	—

Source: authors.

Table 8. **Details about the Interviewees**

Country	Position	Experience in IT (years)	Duration of interview (H)	Procedure
Portugal	IT Manager	18	2h40	Face to face
Portugal	IT Team Leader	8	1h50	Face to face
USA	Application Support Lead	12	1h30	Virtual
Portugal	IT Director	16	1h12	Virtual
Portugal	IT Director	20	1h20	Face to face

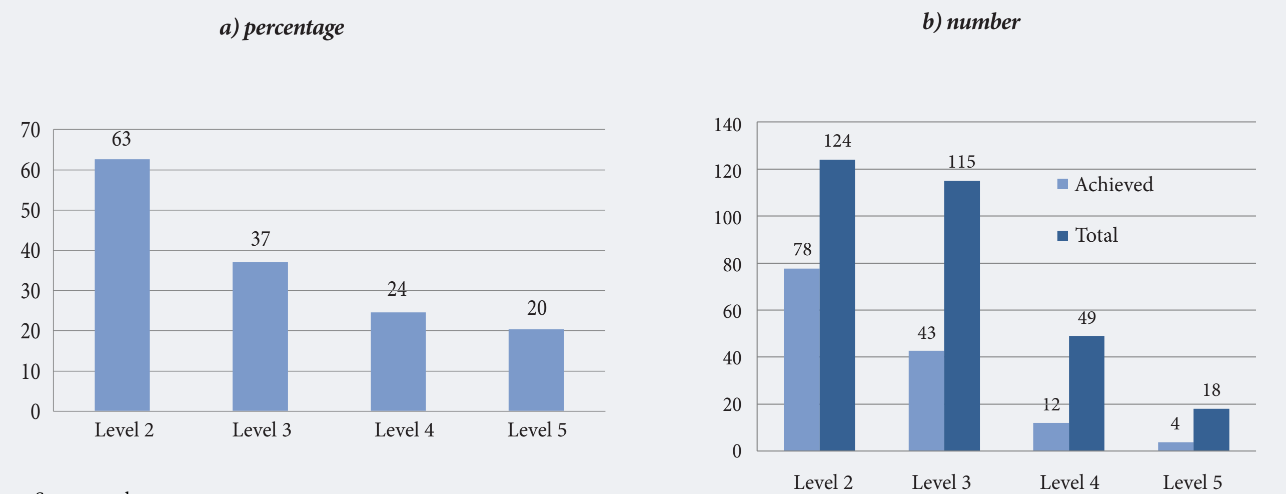
Source: authors.

Table 9. **Factor Analysis and Details about the Interviewee's Organization**

Industry	Size	IT Employees	Market	IT Strategy	IT Structure	Culture
Telecommunication	2100	400	Worldwide	Flexibility	Decentralized	Pyramidal
Energy, Automation and Telecommunication	1400	28	Worldwide	Flexibility	Decentralized	Pyramidal
Pharmaceutical	42 000	1300	Worldwide	Efficiency	Federal	Contest
Software	13 000	—	Worldwide	—	—	—
Banking	—	—	Wordwide	Flexibility	Federal	Pyramidal

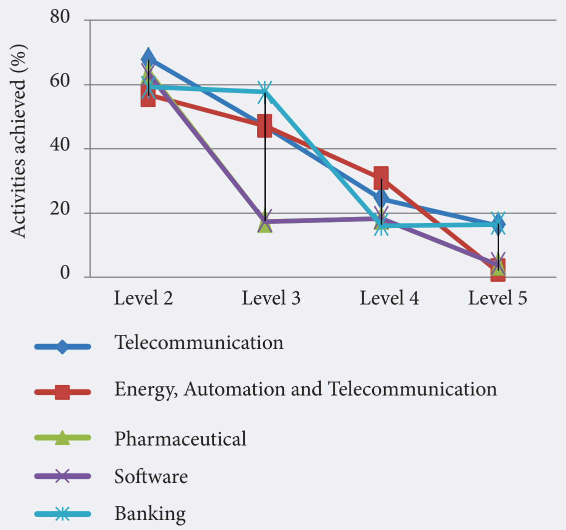
Source: authors.

Figure 2. **Average Implemented Activities (%)**



Source: authors.

Figure 3. **Maturity Level of Each Organization (activities achieved by type of organization)**



Source: authors.

Table 11. **PM MM Evaluation**

Interview number	Completeness	Missing activities	Usefulness
1	Too long / Overtired	No	Yes
2	Very complete	No	Yes
3	Yes	No	Very
4	Very	No	Yes
5	Yes	No	Yes

Source: authors.

and generic [*Pereira, Mira da Silva*, 2012]. Therefore, this research proposes an approach that mitigates some of the existing gaps in multi-framework implementation such as framework overlap and complexity. This research not only confirms the gaps found earlier but aim to solve them with a suggested method that may help organizations in multi-framework implementations. All the interviewees found the approach useful (demonstrated in practice) and complete (no activity was thought to be missing). According to [*de Haes et al.*, 2013; *Aguiar et al.*, 2018], multi-framework implementation is a real challenge. Many organizations are not yet aware of their implementation and fail to yield the best results from them.

A PM MM was then developed by the authors merging all details and knowledge of the three most well-known IT frameworks on the market regarding PM process. During the initial process in the creation of the model, these three IT frameworks (COBIT, CMMI-SVC and ITIL) were analyzed. In the end this research confirmed the existence of overlaps between the IT frameworks. About 13% of the elicited PM activities were common to at least two IT frameworks.

This research provides novel insights for academics given that a new approach absent from the literature was developed merging all the main IT service management frameworks regarding the Problem Management process and tested at real organizations. This may now be assumed as a base for further investigation for the remaining IT service management processes. This research also contributes to the performance of professionals since they now have a tool to assess their Problem Management process maturity. It will help them achieve higher levels of maturity and be aware of current overlaps. Consequently, they may save resources that can be allocated to other processes.

Adding Knowledge by Crossing Studies

Cross-referencing similar studies and findings is an interesting exercise that can be used to evolve the body of knowledge and bring new insights to the scientific community. As previously stated, a similar study [*Aguiar et al.*, 2018] was performed in the past but focused on the IM process instead of PM. The current research was also motivated by the future work proposed by the previous investigation. Table 12 and Table 13 present the information combined from both studies. It is interesting to note that in both studies (Table 12) the highest overlap percentage belongs to the activities common to the three IT frameworks while the lowest belongs to the activities common between COBIT and CMMI-SVC. On the other hand, other findings can be drawn from Table 13. It seems that, when looking for

Table 10. **Analysis of the Adoption of Each IT Framework within the Model**

Models	ITIL	CMMI-SVC	COBIT	ITIL& CMMI-SVC	ITIL& COBIT	CMMI-SVC & COBIT	All	Total
Overall activities (number)	101	89	73	7	11	3	19	303
Overall activities (%)	33.33	29.37	24.09	2.31	3.63	0.99	6.27	100
PM process overlap (%)				**2.31**	**3.63**	**0.99**	**6.27**	**13.20**
Average implemented activities (number)	90	72	65	4	9	2	15	257
Average/Total implemented activities (%)	29.70	23.76	21.45	1.32	2.97	0.66	4.95	—
Average/Overall implemented (%)	89.11	80.90	89.04	57.14	81.82	66.67	78.95	—

Source: authors.

Table 12. **Cross-Study: Overlapped Activities** (%)

Overlapped Activities	ITIL & CMMI SVC	ITIL & COBIT	CMMI-SVC & COBIT	All	Total
Incident Management	5.3	2.4	1.4	14.5	23.6
Problem Management	2.31	3.63	0.99	6.27	13.20

Note: the colored cells in dark and light represent the minimum and maximum of some specific frameworks.
Source: authors.

Table 13. **Cross-Study: Implemented Activities** (%)

Implemented Activities	ITIL	CMMI-SVC	COBIT	ITIL& CMMI-SVC	ITIL& COBIT	CMMI-SVC & COBIT	All
Incident Management	70.1	79.0	72.2	77.4	62.5	71.4	84.1
Problem Management	89.11	80.90	89.04	57.14	81.82	66.67	78.95

both processes, organizations have different preferences regarding which IT frameworks to implement.

Conclusion

This research aims to create an approach to help organizations in multi-framework implementation by eliminating overlaps among IT frameworks. To do so, the authors chose one of the most relevant IT processes (PM) and developed an overlap-less PM MM. The validity of this new approach was confirmed by applying and evaluating it at five different organizations.

This research confirms and reinforces the issue of IT framework overlaps previously identified by other researchers. From the 349 PM activities elicited, 46 activities were identified as being areas of overlap among the chosen IT frameworks. Almost 15% of all activities are present in at least two of the three IT frameworks analyzed in this research (Table 10).

All the interviewees considered the approach useful and complete. They confirmed that implementing an IT framework is not straightforward and having a method to help them in multi-framework implementation would be very useful [*de Haes et al.*, 2013; *Aguiar et al.*, 2018]. By recognizing the proposed method as complete, the interviewees (PM experts) confirm that it is helpful. Looking at the assessed organizations, four of them (80%) pointed to ITIL as the official IT framework. The fifth organization (20%) adopted CMMI. It is interesting to note that despite none of the assessed organizations reaching level 2, they have been implementing the PM process in a balanced way.

From a cross studies analysis, both processes (IM and PM) tend to have the highest percentage of activities overlapped by all the IT frameworks and the lowest percentage of activities common between COBIT and CMMI-SVC.

This research also has some limitations. The authors think that the previous conclusions may change when considering the remaining IT processes and within different organizational contexts. Built on such limitations, future work may assess the model at more organizations and consequently develop similar MMs for the rest of the existing IT processes. It is also authors' conviction that, having an integrated model able to cover most of the adopted IT processes could be very useful and at the same time challenging, which stands as a reason to continue this research.

References

Aguiar J., Pereira R., Vasconcelos J. B., Bianchi I. (2018) An Overlapless Incident Management Maturity Model for Multi-Framework Assessment (ITIL, COBIT, CMMI-SVC). *Interdisciplinary Journal of Information, Knowledge, and Management*, 13, 137–163. https://doi.org/10.28945/4083

Ayat M., Sharifi M., Sahibudin S., Ibrahim S. (2009) *Adoption factors and implementation steps of ITSM in the target organizations*. Paper presented at the 2009 Third Asia International Conference on Modelling & Simulation 25–29 May 2009 Bundang, Indonesia. https://doi.org/10.1109/AMS.2009.114

Becker J., Knackstedt R., Pöppelbuß J. (2009) Developing Maturity Models for IT Management. *Business & Information Systems Engineering*, 1(3), 213–222. https://doi.org/10.1007/s12599-009-0044-5

Bianchi I.S., Sousa R.D., Pereira R. (2017) *IT Governance Mechanisms at Universities: An Exploratory Study*. Paper presented at the Twenty-third Americas Conference on Information Systems, August 2017, Boston, USA. https://www.researchgate.net/publication/319141074_IT_governance_Mechanisms_at_Universities_An_Exploratory_Study, accessed 16.05.2021.

Bovim A., Johnston K., Kabanda S., Tanner M., Stander A. (2014) *ITIL adoption in South African: A Capability Maturity view.* Paper presented at the E-Skills for Knowledge Production and Innovation Conference 2014, Cape Town, South Africa. http://proceedings.e-skillsconference.org/2014/e-skills049-060Bovim759.pdf, accessed 17.06.2021.

Carvalho J.V., Rocha Á., Abreu A. (2019a) Maturity Assessment Methodology for HISM M — Hospital Information System Maturity Model. *Journal of Medical Systems*, 43(2), 35. https://doi.org/10.1007/s10916-018-1143-y

Carvalho J.V., Rocha Á., van de Wetering R., Abreu A. (2019b) A maturity model for hospital information systems. *Journal of Business Research*, 94, 388–399. https://doi.org/10.1016/J.JBUSRES.2017.12.012

Cater-Steel A., Tan W.-G., Toleman M. (2006) *Challenge of adopting multiple process improvement frameworks*. Paper presented at the 14th European Conference on Information Systems, ECIS 2006, Göteborg, Sweden, 2006. https://www.researchgate.net/publication/221408576_Challenge_of_adopting_multiple_process_improvement_frameworks, accessed 10.05.2021.

De Bruin T., Freeze R., Kulkarni U., Rosemann M., Freeze R., Carey W.P. (2005) *Understanding the Main Phases of Developing a Maturity Assessment Model*. Paper presented at the 16th Australian Conference on Information Systems (ACIS 2005). http://aisel.aisnet.org/acis2005, accessed 08.06.2021.

De Haes S., van Grembergen W. (eds.) (2017) *Strategic IT governance and alignment in business settings*. Hershey, PA: IGI Global. https://doi.org/10.4018/978-1-5225-0861-8

De Haes S., van Grembergen W., Debreceny R.S. (2013) COBIT 5 and Enterprise Governance of Information Technology: Building Blocks and Research Opportunities. *Journal of Information Systems*, 27(1), 307–324. https://doi.org/10.2308/isys-50422

De Maere K., De Haes S. (2017) *Is the Design Science Approach fit for IT Governance Research?* Paper presented at the 16th European Conference on Research Methodology for Business and Management Studies, June 2017, Dublin. https://www.proquest.com/openview/d898b4819205b18146e1bddd65bd615a/1?pq-origsite=gscholar&cbl=1796413#:~:text=The%20results%20suggest%20that%20top,elements%20in%20their%20research%20design, accessed 24.01.2021.

Evelina E., Pia G., David H., von Würtemberg L.M., Waldo R.F. (2010) *Process improvement framework evaluation*. Paper presented at the 17th International Conference on Management Science & Engineering, 24–26 November 2010, Melbourne, VIC, Australia. DOI: 10.1109/ICMSE.2010.5719823.

Flores J., Rusu L., Johannesson P. (2011) *A Maturity Model of IT Service Delivery.* Paper presented at the International Conference on Information Resources Management (CONF-IRM), June 2011. https://aisel.aisnet.org/cgi/viewcontent.cgi?article=1009&context=confirm2011, accessed 12.06.2021.

Gama N., Sousa P., da Silva M.M. (2013) Integrating Enterprise Architecture and IT Service Management. In: *Building Sustainable Information Systems* (eds. H. Linger, J. Fisher, A. Barnden, C. Barry, M. Lang, C. Schneider), Heidelberg, Dordrecht, London, New York: Springer, 153–165. https://doi.org/10.1007/978-1-4614-7540-8_12

Gregor S., Hevner A.R. (2013) Positioning and Presenting Design Science Research for Maximum Impact. *MIS Quarterly*, 37(2), 337–355. https://doi.org/10.2753/MIS0742-1222240302

Herrera M., van Hillegersberg J. (2019) *Using Metamodeling to Represent Lean Six Sigma for IT Service Improvement*. Paper presented at the 21st IEEE Conference on Business Informatics (CBI), 15–17 July 2019, Moscow, Russia. https://doi.org/10.1109/CBI.2019.00034

Hevner A.R., March S.T., Park J., Ram S. (2004) Design Science in Information Systems Research. *MIS Quarterly*, 28(1), 75–105. https://doi.org/10.2307/25148625

Huygh T., De Haes S., Joshi A., van Grembergen W. (2018) *Answering key global IT management concerns through IT governance and management processes: A COBIT 5 view*. Paper presented at the 51st Hawaii International Conference on System Sciences. DOI: 10.24251/HICSS.2018.665

ISACA (2012) *COBIT 5: Enabling Processes*, Schaumburg, IL: Information Systems Audit and Control Association.

ISACA (2013) *COBIT 5: Process Assessment Model (PAM)*, Schaumburg, IL: Information Systems Audit and Control Association.

Jansen S. (2020) A focus area maturity model for software ecosystem governance. *Information and Software Technology,* 118, 106219. https://doi.org/10.1016/j.infsof.2019.106219

Kappelman L., Johnson V., Torres R., Maurer C., McLean E. (2019) A study of information systems issues, practices, and leadership in Europe. *European Journal of Information Systems*, 28(1), 26–42. https://doi.org/10.1080/0960085X.2018.1497929

Long J.O. (2008) *ITIL® Version 3 at a Glance: Information Quick Reference*, Heidelberg, Dordrecht, London, New York: Springer, https://doi.org/10.1007/978-0-387-77393-3

March S.T., Smith G.F. (1995) Design and natural science research on information technology. *Descision Support Systems*, 15(4), 251–266. https://doi.org/10.1016/0167-9236(94)00041-2

Matthyssens P., Wursten H. (2002) Internal Marketing. *Cross-cultural marketing* (eds. R. Rugimbana, S. Nwankwo), Toronto, ON: Thompson Educational Publishing, pp. 243–256.

Patón-Romero J.D., Baldassarre M.T., Rodríguez M., Piattini M. (2018) Green IT Governance and Management based on ISO/IEC 15504. *Computer Standards & Interfaces*, 60, 26–36. https://doi.org/10.1016/J.CSI.2018.04.005

Peffers K.E.N., Tuunanen T., Rothenberger M.A., Chatterjee S. (2007) A Design Science Research Methodology for Information Systems Research. *Journal of Management Information Systems*, 24(3), 45–77. https://doi.org/10.2307/40398896

Pereira R., Almeida R., Mira da Silva M. (2013) *How to Generalize an Information Technology Case Study.* Paper presented at the 8th Design Science Research in Information Systems and Technology (DESRIST), June 11–12, 2013, Helsinki, Finland. https://doi.org/10.1007/978-3-642-38827-9_11

Pereira R., Mira da Silva M. (2010) *ITIL maturity model.* Paper presented at the 2010 5th Iberian Conference on Information Systems and Technologies (CISTI), June 16–19, Santiago de Compostela, Spain.

Pereira R., Mira da Silva M. (2011) *A Maturity Model for Implementing ITILv3.* Paper presented at the IEEE 15th International Enterprise Distributed Object Computing Conference Workshops, 29 August – 2 September 2011, Helsinki, Finland. DOI: 10.1109/EDOCW.2011.30

Pereira R., Mira da Silva M. (2012) Designing a new integrated IT governance and IT management framework based on both scientific and practitioner viewpoint. *International Journal of Enterprise Information Systems (IJEIS)*, 8(4), 1–43. https://doi.org/doi:10.4018/jeis.2012100101

Rai A. (2017) Diversity of Design Science Research. *MIS Quarterly*, 41(1), 3–18. https://aisel.aisnet.org/misq/vol41/iss1/2, accessed 19.11.2020.

Rohloff M. (2008) *A Reference Process Model for IT Service Management*. Paper presented at the AMCIS 2008 Conference, 14–17 August 2008, Toronto, ON, Canada. http://aisel.aisnet.org/amcis2008/2, accessed 19.11.2020.

Saarelainen K., Jantti M. (2016) Quality and human errors in IT service infrastructures — Human error based root causes of incidents and their categorization. Paper presented at the 11th International Conference on Innovations in Information Technology (IIT), 1-3 November 2015, Dubai, United Arab Emirates. https://doi.org/10.1109/INNOVATIONS.2015.7381541

Sahibudin S., Sharifi M., Ayat M. (2008) *Combining ITIL, COBIT and ISO/IEC 27002 in order to design a comprehensive IT framework in organizations*. Paper presented at the 2nd Asia International Conference on Modelling & Simulation (AMS), 13–15 May 2008, Kuala Lumpur, Malaysia. https://doi.org/10.1109/AMS.2008.145

Schlarman S. (2007) Selecting an IT control framework. *Information Systems Security*, 16(3), 147–151. https://doi.org/10.1080/10658980701225440

SEI (2010) *CMMI® for Services, Version 1.3 CMMI-SVC, V1.3 Improving processes for providing better services*, Pittsburgh, PA: Software Engineering Institute.

Serenko A., Bontis N., Hull E. (2016) An application of the knowledge management maturity model: The case of credit unions. *Knowledge Management Research & Practice*, 14(3), 338–352. https://doi.org/10.1057/kmrp.2014.37

Sharifi M., Ayat M., Ibrahim S., Sahibuddin S. (2009) The most applicable KPIs of problem management process in organizations. *International Journal of Simulation: Systems, Science and Technology*, 10(3), 77–83. http://ijssst.info/Vol-10/No-3/paper8.pdf, accessed 22.06.2021.

Simonsson M., Johnson P., Wijkström H. (2007) *Model-Based IT Governance Maturity Assessments with Cobit*. Paper presented at the 15th European Conference on Information Systems, ECIS 2007, St. Gallen, Switzerland. http://aisel.aisnet.org/ecis2007, accessed 17.11.2020.

Tan W.-G., Cater-Steel A., Toleman M. (2010) Implementing IT service management: A case study focusing on critical success factors. *Journal of Computer Information Systems*, 50(2), 1–12. https://doi.org/10.1080/08874417.2009.11645379

Uskarcı A., Demirörs O. (2017) Do staged maturity models result in organization-wide continuous process improvement? Insight from employees. *Computer Standards and Interfaces*, 52, 25–40. https://doi.org/10.1016/j.csi.2017.01.008

Venable J.R., Pries-Heje J., Baskerville R. (2017) *Choosing a Design Science Research Methodology.* Paper presented at the 28th Australasian Conference on Information Systems, 4–6 December 2017, Hobart, Australia. http://hdl.handle.net/20.500.11937/70119, accessed 18.05.2020.

Vitoriano M.A.V., Neto J.S. (2016) Information technology service management processes maturity in the Brazilian Federal direct administration. *Journal of Information Systems and Technology Management*, 12(3), 663–686. https://doi.org/10.4301/S1807-17752015000300009

Webster J., Watson R.T. (2002) Analyzing the Past to Prepare for the Future: Writing a Literature Review. *MIS Quarterly*, 26(2), 13–23. https://doi.org/10.1.1.104.6570

Teaching Foresight and Futures Literacy and Its Integration into University Curriculum

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

Bialystok University of Technology 45 AWiejska Street, 15-351 Bialystok, Poland

Anna Sacio-Szymańska
Researcher [a] and beFORE Project Coordinator [b], anna@4cf.pl

[a] 4CF Strategic Foresight, Plac Trzech Krzyzy 10/14, 00-499 Warszawa, Poland
[b] Lukasiewicz Research Network — Institute for Sustainable Technologies, K. Pulaskiego 6/10, 26-600 Radom, Poland

Stefanie Ollenburg
Researcher, s.ollenburg@fu-berlin.de

Freie Universitaet Berlin, Fabeckstr. 37, 14195 Berlin, Germany

Leonello Trivelli
Researcher, leo.trivelli@gmail.com

University of Pisa, Department of Civil and Industrial Engineering, Largo L. Lazzarino 56122, Pisa, Italy

Abstract

Despite the accelerated dynamics of the environment, higher education institutions slowly update their curricula in entrepreneurship education according to global challenges and market needs. Moreover, knowledge and good practice exchange between educators of futures studies, business representatives and academics is limited. This article aims to present the methodology of prototyping an online course for individuals to become more future-oriented in their professional and personal settings. The main research problems tackled by the authors relate to: 1) identification of competences that would help academics, entrepreneurs and students to deal with uncertainty and to 2) convey the competences to the target groups through learning topics selected from futures studies and the entrepreneurship repertoire. The authors of the article undertook and coordinated theoretical and empirical research on foresight and futures literacy and its correspondence with entrepreneurship within the beFORE project funded under the Erasmus+ programme Knowledge Alliance scheme. The research process resulted in identification of 12 key competence items and development of the free approximately 34 hours long online course consisting of seven self-standing modules, 25 lessons and 79 learning topics corresponding to these competences. The originality of the paper is in its contribution to the discussion on the competences and online course contents that efficiently increase the capacities of using the future(s) in professional, academic and personal settings.

Keywords: foresight; long-term strategies; future-orientation; Futures Literacy; entrepreneurship; competences; eLearning

Citation: Kononiuk A., Sacio-Szymańska A., Ollenburg S., Trivelli L. (2021) Teaching Foresight and Futures Literacy and Its Integration into University Curriculum. *Foresight and STI Governance*, 15(3), 105–121. DOI: 10.17323/2500-2597.2021.3.105.121

Introduction

For a long time, entrepreneurs were thought to be "bearers of uncertainty" [*Knight*, 1921], disruptors of market equilibria [*Schumpeter*, 1934] or the source of changes that result in the establishment of equilibria [*Walras*, 1954]. Indeed, the ability to envision new contexts in which products and services would be able to delineate different ways of life and new forms of society and wealth has always been one of the most characterizing traits of entrepreneurs.

After 2009, the European Commission underlined the importance of entrepreneurship in its Entrepreneurship Action Plan which stated that having a higher number of entrepreneurs would help Europe return to a growth trajectory [European Commission, 2012]. At the same time, a growing number of initiatives aimed at supporting the creation of new companies started all over the world [*Bridge*, 2017] and entrepreneurship education programs considerably increased in the last few years [*Jones et al.*, 2018]. According to [*Thomassen et al.*, 2018], entrepreneurship education has been widely investigated in recent decades with the goal of framing which aspects might be taught and which skills are the more important to train new entrepreneurs.

Entrepreneurial skills and competences taught to students during their time at university are limited to financial [*Ratcliffe, Ratcliffe*, 2015], economic literacy [*Fontela*, 2006], and human resources management [*Hurst,* 2014].

Meanwhile, future and acting entrepreneurs need open access to knowledge about models, methods, and tools, which should enable them to build and constantly reinvent so-called future-proof strategies. These are the strategies, which take into account potential future challenges and opportunities, which question assumptions about the future to find the load-bearing solutions. These are the ones upon which the plan rests in order to seek solutions that are implementable in the context of various alternative scenarios and the organizational external environment. Developing such strategies requires competences of futures thinking and/or futures literacy.[1]

In this paper we argue that futures thinking is the competence that should complement curricula taught at faculties of entrepreneurship and we present a methodology for prototyping an online course in futures thinking with the ambitious goal of producing futures literate individuals and entrepreneurs.[2]

In our competence-based methodological approach, we blend the theory of futures studies and the practice of strategic foresight, in a part that refers to individual or organizational futures thinking ability [*Hines et al.*, 2017; *Dannenberg, Grapentin*, 2016; *Ratcliffe, Ratcliffe*, 2015; *van der Laan, Erwee*, 2012; *Rohrbeck*, 2011].

In this article, we refer to futures thinking as synonymous with futures literacy. We perceive both futures literacy and futures thinking as competences to cope with the future. Futures studies offer a range of tools to support futures thinking and the identification and interaction of trends, such as trend analyses, scenario methods, which help to structure thinking about the future and thus make futures thinking and futures literacy learned competences. We argue that those competences should become skills for the 21st century just like digital literacy, internet literacy, or information literacy [*Stordy,* 2015]. Similarly to futures thinking, we treat the term literacy as the capability not only to imagine the future or futures but also to create it in more diverse ways for different purposes, which can be seen as a competence that allows entrepreneurs to address 21st century challenges [*Miller,* 2018]. Therefore, our ambition is to make it a learned skill by offering a free, approximately 34-hour-long online course on foresight and futures literacy.

Research Objective and Questions

The capability of futures thinking and/or futures literacy as well as related competences can be further developed through exposure to the discourse on futures concepts, methods for studying the future, and its applications [*Alsan*, 2008; *Miller*, 2018].

Building on previous research [*Nanus* 1997; *Alsan* 2008; *Miller* 2018] we hypothesize that introducing the theory of futures studies and the practice of strategic foresight into entrepreneurial education and business culture can enhance futures thinking capabilities and increase resilience skills.

However, despite the relevant contribution that futures literacy can bring to entrepreneurship education, the openness of universities to transforming traditional entrepreneurship curricula is limited [*Clark*, 2003].

Therefore, this research aims to present a methodological approach for the design and implementation of an open access educational course in future-orientated entrepreneurship, delivered through e-learning platforms. As an example, the authors introduce the Erasmus + Knowledge Alliance project entitled: "Becoming future-oriented entrepreneurs in universities and companies – beFORE"[3], its methodology, and the resulting prototype e-learning offer aimed at equipping individuals with futures thinking competences.

The objective of this paper is to further the discussion on the competences and online course content that efficiently increase the capacities of using the future in professional, academic, and personal settings.

Therefore, the research questions that the authors address in the paper are:

- Which **competences** do individuals need to be more future-oriented and in the long term to become futures literate in professional and educational environments?
- Which **educational topics** would best help in developing such competences through one coherent online educational course?

As part of the consortium, the authors reflect upon the beFORE project process to design online training programs (as shown in Figure 1) in order to offer a critical view on ways to identify future-oriented competences through the lens of

[1] Futures Literacy is a cognitive competence, which allows one to: creatively envision possible futures, discover assumptions about the future, reframe and enrich future visions, expand the boundaries of perception of the present and make sense of the present, sense and describe change, stimulate initiative and agency — accordingly with or against changes/shocks, and enhance reflexivity [Miller, 2018].

[2] The definition of "entrepreneur" that we apply in this paper is: a "person having the ability to accurately assess situations, people, facts and events and turn this to one's advantage." (Online Oxford dictionary 2017). https://english.stackexchange.com/questions/79572/single-word-for-taking-advantage-of-the-situation, accessed 14.05.2021.

[3] www.futureoriented.eu, accessed 14.05.2021.

what has been taught (the supply side) and what is most valued by target groups (the demand side).

Identifying Future-Oriented Competences and Learning Needs

Reviewing and synthetizing studies, university curricula, courses and case studies to extract futures literacy, foresight and entrepreneurial competences

As demonstrated in the 2006 European Reference Framework for Key Competences for Lifelong Learning, in a world of high dynamism, unpredictable changes, and volatility [*Kaivo-oja, Laureus,* 2018], futures literate individuals will have a better chance of securing new employment [*Gudanowska et al.* 2020]. Future-oriented thinking is a core competence because it is the foundation for imagination, strategy development, and the creation of a preferred future for individuals and at organizations [*Inayatullah*, 2008]. Foresight competences make a contribution to the successful realization of the strategy in higher education mergers [*Sajwani et al.,* 2021]. In addition to problem-oriented learning, foresight competences that allow for goal-building and developing students' readiness to undertake change should be introduced into educational processes [ETF, 2017]. A similar view related to career guidance training can be found in [*Kononiuk et al.,* 2020]. Foresight competence belongs to the dynamic capabilities of the educational enterprises [*Arpentieva et al.,* 2020]. The authors emphasize that these competences allow for the transformation of organizational routines thus allowing not only for predicting the "unpredictable", but also for a more favorable configuration of organizational resources.

Therefore, the first step of the presented research is the identification of future-oriented competences which could be relevant to integrate into entrepreneurship education programs. The authors of this article understand competences as the knowledge and skills that are indispensable for carrying out specific tasks in an effective way [*Volpentesta, Felicetti*, 2011; *Gudanowska et al.*, 2020]. In line with [*Suleiman, Abahre,* 2020], the authors of the article perceive competences as personal dispositional capabilities used to act successfully in new situations.

The literature review implies that a multitude of competences are considered essential or at least useful for future-oriented entrepreneurs. The examples of future-oriented entrepreneur competences retrieved from the publications are presented in Table 1.

Entrepreneurial competences that are often mentioned in the existing publications are: lack of risk-aversion *[Jain*, 2011], high risk management skills [*Morris et al*., 2013], creativity [*Bell*, 2009; *Rohrbeck*, 2011], innovativeness, internal locus of control [*Jain*, 2011], networking skills, and the ability to identify opportunities [*Rohrbeck*, 2011] and learn from mistakes [*Lewrick* et al, 2010] .

On the other hand, foresight competences should liberate the mind from its old assumptions and sensitize it to the earliest signals of change [*Weiner, Brown,* 2008]. Therefore, among the foresight competences mentioned by these authors are: the acceptance of signals of change, challenging assumptions, looking at a problem from many perspectives, propensity to identify countertrends, understanding complexity, the ability to see the whole context, understanding evolutionary changes, questioning consensus, and understanding the dangers of efficiency which may threaten a less appreciated source of competitive advantage: resilience [*Martin,* 2019]. Foresight competences are not the same as entrepreneurial competences per se but may be considered supportive.

The literature review demonstrated that authors focused on different competences, mainly due to the school of thought (of foresight/futures studies) they adhere to as well as how they "use" the future as a concept. Therefore, the competences mentioned focus either more on analytical skills [*Bell*, 1997], creativity [*Chiu*, 2012], reflective and social skills [*Inayatullah*, 2008; *Ratcliffe, Ratcliffe*, 2015], interdisciplinary anticipation in thinking and acting [*Dannenberg, Grapertin*, 2016], or exploring the potential of the present to give rise to the future [*Miller,* 2018].

The literature review focused on the competences of individuals, rather than on organizational capabilities. However, the state-of-the-art analysis also included selected works [*Rohrbeck*, 2011; *Grim*, 2009; *Fuller et al.,* 2008;], which provided the authors of the article with a broader context of entrepreneurship and foresight research, resulting in specifying critical organizational future-orientation capabilities. These relate to information usage, method sophistication, people and networks, organization, culture [*Rohrbeck*, 2011]; leadership, framing, scanning, forecasting, visioning, planning [*Grim*, 2009]; experimenting, reflexivity, organizing, and sensitivity [*Fuller* et al., 2008]

The literature review has been complemented by an analysis of the best corporate foresight cases and best educational practices following the criteria of indicating best practices [*Xu, Yeah*, 2012] such as: universality of practice, repeatability, its methodological character, and novelty.

In the same way as in the case of the literature review, good business practices were analyzed. The data for the analysis were obtained on the basis of direct contacts with companies, information on company websites, or scientific publications that deal with the issues of competences of a future-oriented entrepreneur [*Hiltunen*, 2013; *Rudzinski, Uerz*, 2014; *Andriopoulos, Gosti*, 2006; *Cuhls, Johnston*, 2008; *Wippel* 2014; *van der Heijden*, 2000; *van Atta et al.* 2011; *Rohrbeck* 2011; *Song, Hormuth* 2013; *Keller*, 2013].

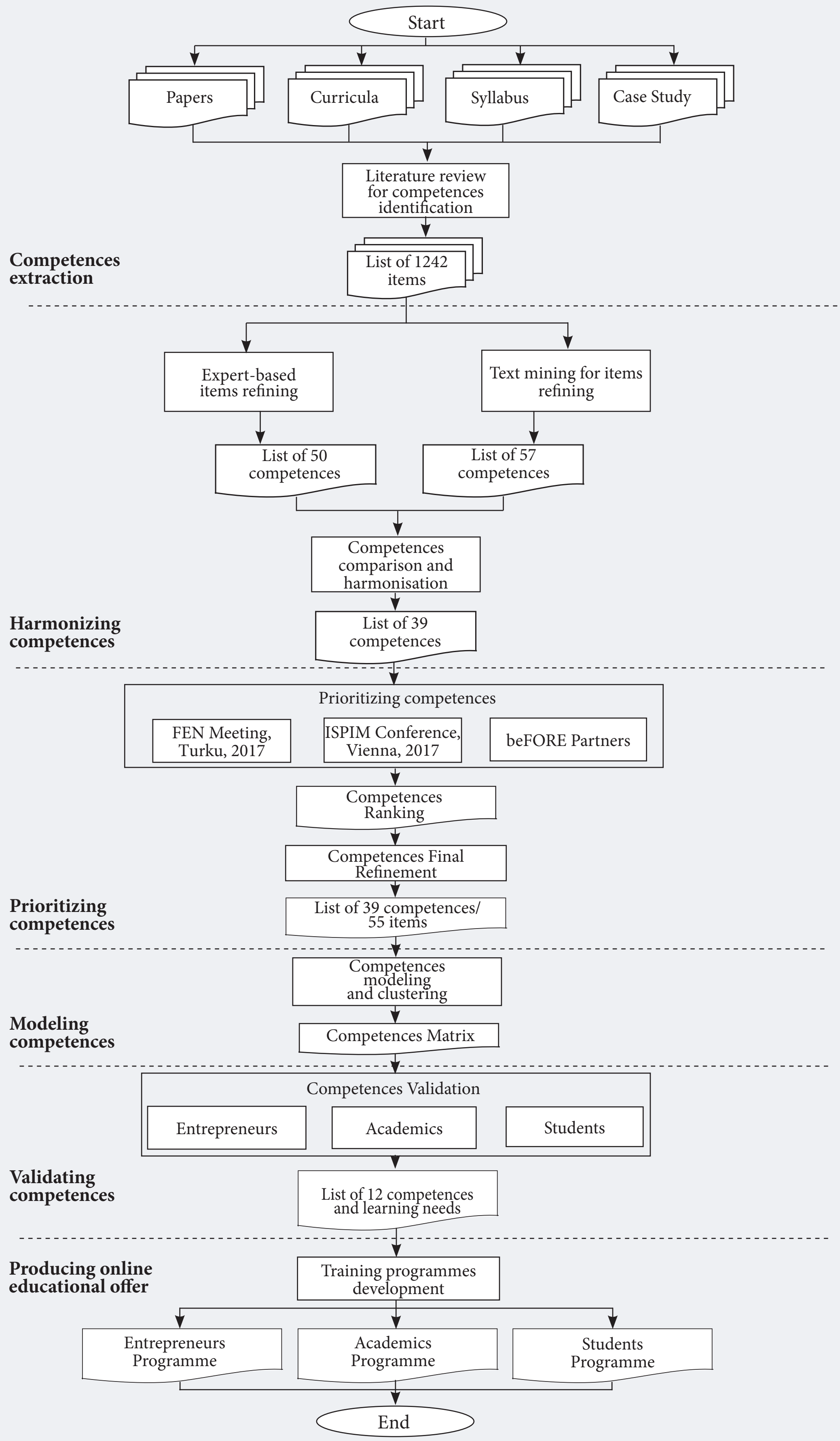
Moreover, the project consortium also investigated 17 foresight courses [*Ejdys et al.,* 2019] conducted worldwide. Existing best educational practices were identified on the basis of the criteria mentioned above and a detailed analysis of the database of higher education offers regarding the convergence among futures studies, entrepreneurship, and innovation. All in all, out of 193 investigated sources, 1,242 items were identified.

Harmonizing futures literacy, foresight, and entrepreneurship competences

The second phase of the process had the goal of harmonizing the 1,242 items identified in the literature review phase.

To pursue such a goal, two concurrent approaches were adopted. The first (top down) was based on a qualitative analysis of the competences performed by the foresight experts. The second (bottom-up) was to analyze the results of the literature review with text mining approaches [*Fareri et al*., 2020; *Lefebvre et al.*, 2013] in order to widely evaluate all appearing phrases and to extract emerging competences from the 1,242 items previously identified. In this way, the authors of the study

Figure 1. **Online Training Program Design Process**



Source: authors.

sought to ensure the triangulation of research methods. This concept in the social sciences should be treated metaphorically – as the evaluation of the phenomenon under study from different points of view in order to better understand its multifaceted nature [*Denzin*, 1978; *Jonsen, Jehn*, 2009] and to improve the reliability of the research process [*Begley*, 1996].

The results of this activity was a pilot list of 39 competences (Box 1).

The list is the result of the literature review, the application of data mining techniques, and the discussions about future-oriented competences of the target groups (students, academics, and business people) held by the project partners.

Prioritizing, modeling, and clustering futures literacy, foresight and entrepreneurship competences

The pilot list of 39 competences was then further evaluated independently by 39 foresight experts and separated into three groups:

- the first group was selected from among the participants of the FEN[4] meeting and the conference Futures of a Complex World (June 13-14, 2017 – Turku, Finland);
- the second group was identified during the XXVIII ISPIM[5] conference (June 18-21, 2017 – Vienna, Austria);
- the third group were selected by the beFORE project partners' representatives from academia and business.

These evaluations were performed through dedicated questionnaires which aimed to identify the most important foresight competences for entrepreneurs, students, and academics. The results of such investigations provided an initial ranking of the 39 competences.

The final step of the competence identification process was the setup of a map which outlined the competences to be acquired by entrepreneurs, academics, and students to develop a future-oriented mindset. In this phase, the competences were re-grouped and put into a conclusive correlation considering the three target groups (i.e., entrepreneurs, academics, and students) as well as their relationship to time (i.e., future orientation). Therefore, to establish a matrix for mapping the competences, a focus was placed on their competence fields, the relevant **target groups**, and the **timeframe** of short-, medium-, and long-term future-orientatio [*Bell*,1997; *Kreibich et al.*, 2011; *Gidley*, 2016].

The following matrix was established where four quadrants define four main competence fields based on EU specifications[6]:

- Knowledge – **"***Cognitive competence* (C) involving the use of theory and concepts, as well as informal tacit knowledge gained experientially…"
- Technical abilities (skills) – "*Functional competence* (F) (skills or know-how), those things that a person should be able to do when they are functioning in a given area of work, learning, or social activity …"
- Social skills – "*Personal competence* (P) involving knowing how to conduct oneself in a specific situation …"
- Self-assessment (reflexive) abilities – "*Ethical competence* (E) involving the possession of certain personal and professional values …"

The X-axis plots the items' relevance on a timeframe of the future. The division considers how a competence relates to future-awareness, decision-making, present/future actions on a personal level, for an organization, the ecosystem, and even globally. The timeframes are:

- short-term – under five years) (S)
- medium-term – five to 20 years (M)
- long-term – 20+ years(L)

The Y-axis plots the items according to the general learning objectives differentiating the target groups:

- Students: to receive **knowledge** / to understand (U)
- Entrepreneurs: to be able to **apply** (A) knowledge
- Educators: to learn how to **educate/teach** (T) said knowledge

The matrix (Figure 2) was the foundation for a mapping workshop to group the competences along the axis in a team effort.

The procedure revealed that there are competences, which may be significant for general education in entrepreneurship or relevant only in the short term but have less effect on the medium/long term or the ability to engage in futures thinking. These phrases were marked in grey to be excluded for further evaluation. The resulting list maps the items along the competence field, the general learning objective, and time (future) frame (Table 2).

Starting from the updated list created thanks to the mapping activity, the project consortium worked to match those complex sentences with the competences identified in the O*NET database (Table 3).

It provided important insights for defining and grouping the competences. In this activity, a list of elements was selected to decompose the 39 competences in items that were specific enough to be considered basic skills and to be taken into consideration according to a common level of granularity.

With this explorative process the project partners were able to define twelve competences (Figure 3).

This reduction of complexity was necessary to get an overview. Although those general competences are not unique for foresight or futures literacy, they overlap with the list of 39 competences.

The relationships developed in the group work by the authors of the article between the 39 competences and the twelve general competences are shown in Table 4. For instance, to be able to define, identify, and analyze trends within the micro- and macroenvironment of a company, one must have the ability to analyze data and information, demonstrate critical thinking and inductive reasoning, and know how to interpret the meaning of information conveyed by trends. Analyzing Table 4, it can also be noted that there are specific competences which are very broad in meaning and require the involvement of all twelve general competences. These include: the ability to manage projects, the ability to develop organizational resilience, the ability to run strategic foresight within an organiza-

[4] FEN is the Foresight Europe Network http://www.feneu.org/, accessed 18.04.2021.

[5] ISPIM is the the International Society for Professional Innovation Management. www.ispim-innovation.com, accessed 22.05.2021.

[6] http://www.eucen.eu/EQFpro/GeneralDocs/FilesFeb09/GLOSSARY.pdf, accessed 09.03.2020.

Table 1. **Future-Oriented Entrepreneur Competences Retrieved from the Publications**

Authors	Selected Competences of Future-Oriented Entrepreneurs
[*Inayatullah,* 2008]	capacity to reflect, i.e. developing an understanding of one's past, present, and expectations for the future ("mapping"), being aware of mostly implicit assumptions on development and change ("timing the future"), being aware of mostly implicit assumptions on epistemological foundations of reality, e.g., discourses and myths (deepening the future); ability to formulate preferences or make conscious choices on a normative basis ("transforming the future"); logical thinking and ability to deduce from historical experiences ("anticipation")
[*Weiner, Brown,* 2008]	acceptance of signals of change, challenging assumptions, looking at a problem from many perspectives, propensity to identify countertrends, understanding complexity, ability to see a whole context, understanding evolutionary changes, questioning consensus, understanding the dangers of efficiency
[*Bell,* 2009]	prospective thinking, i.e., the ability to imagine and explore alternative futures; creativity; lateral thinking, i.e., the ability to imagine futures also going beyond the obvious development; visionary combined with factual thinking – linking images of the future to present day behavior and their consequences
[*Lewrick et al.,* 2010]	ability to learn from mistakes; social skills – understanding the customer's point of view; management capacity/ leadership qualities: making of decisions with new business models in mind, comprehension of the importance of developing measurement systems to control innovation initiatives and strategic direction
[*Jain,* 2011]	ability to discover opportunities, lack of risk-aversion (moderate or high risk-taking propensity — inconclusive research), innovativeness, intuition, tolerance for ambiguity, achievement motivation (tendency to plan, establish future goals, gather information, and learn), internal locus of control, healthy self-esteem, high level of self-efficacy
[*Rohrbeck,* 2011]	ability to capture external data, ability to effectively disseminate information and insights into the organization, ability to look outside company boundaries and continuous scanning of the periphery, ability to translate strategy into action, ability to communicate clearly and concisely, ability to use creativity to identify opportunities and take risks, ability to connect and inspire other people to invest their efforts in new topics, ability to create an environment of trust
[*Chiu,* 2012]	behavioral flexibility; constructing mental representations of possible futures; creative thinking
[*Heinonen, Ruotsa-lainen,* 2012]	interaction competence, collaboration competence, time competence, technology competence, environmental competence, systems competence, socio-cultural sense-making competence
[*van der Laan, Erwee,* 2012]	interrogating the future; future-time orientation , interest in the long-term issues that define the future, envisioning "bigger picture" futures, adjusting to new situations as the future demands, balancing multiples challenges and choices, helping others to adapt, flexible leadership, influencing change, adopting new trends, confirming the diffusion of innovation theory, experimenting with new trends when they arise, opportunistic trend analysis, preserving one's own position, mitigating and resisting change
[*Morris et al.,* 2013]	opportunity recognition, opportunity assessment, risk management/ mitigation, conveying a compelling vision, tenacity/ perseverance, creative problem solving/ imaginativeness, resource leveraging, guerrilla skills, value creation, maintain focus yet adapt, resilience, self-efficacy, building and using networks
[*Ratcliffe, Ratcliffe,* 2015]	awareness of self, situation, and environment, authenticity – values, truth, direction, good spirit, communication, cultivating culture /relationships, audacity challenge, inspire, enable, model, encourage; adaptability – purpose and choices, looking at system from a distance, embracing differences, action – bringing together, managing the "clever" iterative process
[*Dannenberg, Grapentin,* 2016]	integration of new perspectives and a global view in knowledge generation; interdisciplinary anticipation in thinking and acting; identification and assessing risks and uncertainties, acting and planning in cooperation, participation in thinking and acting; identification and assessing risks and uncertainties, showing empathy and solidarity
[*Gheorghiua et al.,* 2016]	ensuring ecosystemic transparency, mapping emerging global trends, among others though horizon scanning mechanisms such as technological radars for weak signals; entrepreneurial dialogue through consensus-seeking consultation instruments involving broad participation
[*Miller,* 2018]	Futures Literacy is understood as an individual's capacity to explore the potential of the present to give rise to the future. Sense-making, seen as the ability to discover, invent, and construct the world around us. Capacity of "sensing the change" and "making sense" of change and of the reality that emerges.

Source: authors' own elaboration on the basis of the literature review..

tion, the ability to deal with complexity, the ability to develop and implement strategies, and the ability to apply future studies' methodologies. In turn, by analyzing the above table in columns, it can be noted, that such general competences as: analyzing data or information, critical thinking, inductive reasoning, interpreting the meaning of information and conveying it to others, reflexive capacity, and thinking creatively are necessary to implement most of the specific competences.

In order to reduce the complexity of the research, twelve general competences were further analyzed.

Validating Competences through a Survey of University Students, Academics, and Business Representatives (Entrepreneurs)

In order to verify and validate the twelve competences (Figure 2), a survey in the form of a questionnaire was submitted to all target groups addressed by the project. The aim of the survey was: a) to have respondents rank the twelve competences according how they are needed in order to deal with the uncertainties of the future and b) to understand and identify the educational needs of entrepreneurs, university students, and academics as the framework when designing adequate online courses to introduce the field of futures studies.

The survey process took over six weeks (from November until mid-December 2017) and was conducted in all four project countries: Germany, Italy, Poland, and Spain. Each project country aimed to reach the following number of respondents:

- Students – 80;
- Academics – 24;
- Entrepreneurs – 16.

The number of respondents was based on the research assumptions envisaged in the feasibility study of the beFore project and the budget allocated for the survey.

The authors did not assume that the sample would be representative of such a wide group of respondents due to the costs of the research, but rather sought to obtain a general

Box 1. A Pilot List of 39 Competences

1. The ability to define, identify, and analyze trends within the micro- and macroenvironment of a company
2. The ability to find and interpret weak signals of change and disruptions (wild cards and abnormal phenomena)
3. The ability to identify factors influencing the use of strategic foresight by companies
4. The ability to define measurable goals to create a preferred future vision for the organization
5. The ability to work in teams
6. The ability to possess guerilla skills to challenge assumptions
7. The ability to gather, analyze processes, and interpret data (also using IT tools)
8. The ability to act proactively (autonomous strategic behavior, enterprising spirit)
9. Reflexive capacity
10. The ability to develop measurement systems to control innovation initiatives and strategic direction
11. Coaching skills
12. The ability to communicate internally, on an interdisciplinary basis, and with stakeholders
13. The ability to manage projects
14. The ability to develop organizational resilience
15. The ability to run strategic foresight within an organization
16. Systemic thinking
17. Risk-taking capability
18. The ability to manage change and uncertainty (also dynamic capability)
19. The ability to build networks both internally and externally
20. The ability to deal with complexity
21. Understanding dangers of efficiency
22. The ability to develop and implement strategies
23. Time competence (time-organizing skills, utilizing real-time, making optimal use of the diversities of time, appreciation of slow life, developing futures thinking, and futures consciousness)
24. The ability to think out of the box
25. The ability to transform new ideas into business practices
26. Capacity for design thinking
27. The ability to implement the scenario approach within an organization
28. The ability to create an organizational vision (both collective and individual)
29. The ability to identify goods or services that people want
30. Accepting incompleteness of knowledge
31. Non-linear thinking
32. The ability to apply various future studies' methodologies
33. The ability to implement selected methods of technology management (technology assessment, technology mapping, technology life cycle, prioritisation, technology audit, and roadmapping)
34. The ability to perceive unmet consumer needs
35. The ability to look for products that provide real benefit
36. Seizing high-quality business opportunities
37. Maximizing results in resource allocation
38. Seeing the big picture
39. Tolerance of ambiguity

Source: [*Kononiuk et al.*, 2017].

opinion on the respondents' preferences regarding competences. All in all, the project consortium managed to reach 190 students, 75 academics, and 81 entrepreneurs in the four countries (346 respondents in total). The consortium chose to follow a non-probability sampling method (purposive sampling) to achieve a maximum of variety throughout university faculties and entrepreneurial branches. The survey included quantitative as well as qualitative questions. The questionnaire was divided into three parts: respondents rated the twelve competences according (I) to their present educational and vocational situation; (II) to their expected future needs in their working life, and (III) general information to obtain, for example, an overview of the respondents' knowledge of the field [beFORE, 2018].[7]

In part I and II the ranking of the competences were evaluated quantitatively through the use of a scale from "1" – the maximum ranking to "6" – the minimum. The details of the survey evaluation process go beyond the scope of this paper and can be reviewed in [beFORE, 2018].

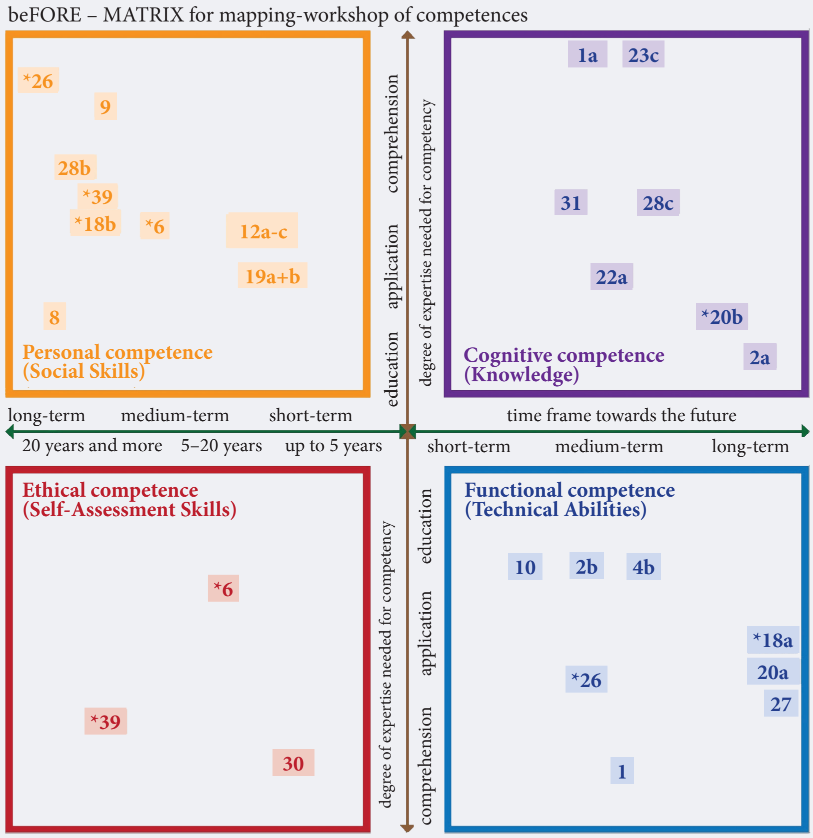
The qualitative questions were involved in part II and III. In II they asked the respondents to reflect on their future professional situation and how it could change in 10-15 years' time (including global or personal changes, challenges, goals, and job titles). In part III of the questionnaire, the respondents were asked to clarify how familiar they were with the terms "foresight" and "futures literacy" and which online learning methods they prefer.

"Adaptability/Flexibility", "Critical Thinking", "Thinking Creatively", "Analyzing Data or Information", "Developing Objectives and Strategies", and "Making Decisions and Solving Problems" (Table 5) were the six highest ranking competences of the twelve assessed in the survey.

[7] The qualitative nature of the survey (many open, thought-provoking questions) resulted in a relatively high number of personal or telephone interviews when executing the survey (it was specifically the case with the entrepreneur group).

Figure 2. **Matrix with Results after Mapping Exercise**

1. To define and identify trends within the micro- and macro-environment of the (company) organization
1a. To define and identify trends within the micro- and macro-environment of the company
2a. To find (to seek?) weak signals of change and disruptions (wild cards and abnormal phenomena)
2b. To interpret weak signals of change and disruptions (wild cards and abnormal phenomena)"
4b. To set / create preferred future vision for the organization
*6. To possess guerrilla skills to challenge assumptions
8. To act proactively (autonomous strategic behavior, enterprising spirit)
9. To have reflexive capacity
10. To develop measurement system to control innovation initiatives and strategic direction
12a-c. To communicate internally, interdisciplinary, with stakeholders
*18a. To manage change and uncertainty (also dynamic capability)
*18b. To manage [(new) to communicate?] change and uncertainty
19a+b. To build networks internally and externally
*20b. To understand complexity
22a. To develop strategies
23c. To understand diversities of time
*26. To have the capacity for design(erly) thinking
27. To implement scenario approach within organization
28b. To create an individual vision
28c. To collectively develop a vision within / for an organization
30. To accept incompleteness of knowledge
31. To have the capability to engage in nonlinear thinking
39. To tolerate ambiguity



Source: authors.

Worth emphasizing is the fact that significant differences between both different countries and target groups were not noticed. In studies on education for sustainable development, the data showed similar results. There the respondents emphasized the relevance of competences that support the shaping and transformation of future developments [Rieckmann, 2011]. This confirms the results in the beFORE project survey and the relevance of future-oriented competences that go beyond analytical skills to include critical thinking, adaptability, and creative skills.

Slightly larger differences between the target groups (academics vs. students vs. entrepreneurs) occurred in the case of the open questions, especially those related to personal achievements, aspirations, and visions of the future. As the target groups differ in age and are at different stages of life, this was a rather expected outcome. For example, to the question about the changes that were expected to have the greatest impact upon the respondents' future jobs, students expected the greatest changes in their personal life (i.e., starting of a family, migration, etc.) 58% compared to 32% in the case of academics and 27% in the case of entrepreneurs. Commonalities in the target groups were found in their expectations regarding changes that will have the greatest impact upon future working conditions are: 'Technological development of discoveries from scientific research" (46% of all respondents and more than 100 specific examples provided) [beFORE, 2018].

The results of the assessment of the twelve 'future-oriented' competences (Figure 2) and the personal need to improve them (now and in the future) was one pillar in the process of creating the e-learning courses. The other pillar was from the qualitative evaluation and assessing the relevant topics: the readiness to establish one's own company in the future or the awareness of foresight or futures thinking, to name just a few. Taking into consideration the research sample (n = 346 respondents) and the survey's high descriptive value, the extensive survey was worthwhile. The consortium received a better understanding of the target groups' needs and was able to build a flexible structure for the e-learning platform that is appealing to all learners.

Producing the Online Educational Offer

Research result as the foundation for developing the pedagogical structure

The main conclusions and recommendations arising from the needs analysis gave insights allowing one to find an adequate pedagogical approach, structures, as well as learning objectives, suitable didactic tools, and methods. The survey did reveal that most survey participants favor studying case studies and projects that demonstrate how to apply foresight and futures literacy methodologies in real life. The preference for case studies in online courses is also confirmed by e-learning experts [*Clark, Mayer,* 2016]. Hence, the use of the competence-based approach has become an important aspect of reflections on course content design and didactical choices. Taking into consideration the pedagogical approach, de Haan [*de Haan,* 2010] highlights the importance of arrangements

Table 2. **After Mapping Exercise: List of 55 Items (39 Rephrased Competences)**

Competences	Mapped as
01a. To define trends within the micro- and macro-environment of the company	C/L/U
01b. To identify trends within the micro- and macro-environment of the company	C/L/U
01c. To analyze trends within the micro- and macro-environment of the company	F/S/A
02a. To find (to seek?) weak signals of change and disruptions (wild cards and abnormal phenomena)	C/L/T
02b. To interpret weak signals of change and disruptions (wild cards and abnormal phenomena)"	F/M/A
03. To identify factors influencing the use of strategic foresight by companies	F/S/A
04. To define measurable goals to create a preferred future vision for the organization	F/M/A
05. To work in teams	P/S/A
06. To possess guerrilla skills to challenge assumptions	P-E/M/A
07a. To gather data (also using IT tools)	F/S/A-U
07b. To analyze and process data (also using IT tools)	C/S/A
07c. To interpret data (also using IT tools)	C/S/U
08. To act proactively (autonomous strategic behavior, enterprising spirit)	P/L-M-S/T
09. To have reflexive capacity	P/L-M-S/U
10. To develop a measurement system to control innovation initiatives and strategic direction	F/S-M/A
11. To possess coaching skills	F-P/ M/T-A-U
12a-c. To communicate internally, in an interdisciplinary manner, with stakeholders	P/S-M/A
13. To manage projects	F/S/A
14. To develop organizational resilience	F/L/E
15. To run strategic foresight within an organization	F/M-L/A
16. To understand systemic thinking	C/L/U
17. To have risk-taking capability	P/S/T
18a. To manage change and uncertainty (also dynamic capability)	F/S-L/A
19a-b. To build networks internally and externally	P/M/A
20. To deal with complexity	F/M/A
21. To understand the dangers of efficiency	E/M/U
22a. To develop strategies	C/M/A
22b. To implement strategies	F/S/A
23a. To have time-organizing skills	F/S/A
23b. To utilize real-time	F/S/A
23c. To make optimal use of the diversities of time	C/M-L/U
23d. To appreciate a slow life	E/S/U
23e-f. To develop futures thinking and futures consciousness	C/L/U
24. To think out of the box	P/L/U
25. To transform new ideas into business practices	F/L/A
26. To have the capacity for design thinking	F-P/M-L/A
27. To implement the scenario approach within an organization	F/S-L/A
28a. To create an organizational vision	C/M/A
28b. To create an individual vision	P/M-L/A
28c. To collectively develop a vision within / for an organization	C/M/A
29. To identify goods or services people want	C/S/U
30. To accept incompleteness of knowledge	E/S/U
31. To have the capability to engage in nonlinear thinking	C/M/A
32. To apply various future studies' methodologies	F/S/A
33. To implement selected methods of technology management (technology assessment, technology mapping, technology life cycle, prioritization, technology audit, and road-mapping)	F/S/A
34. To perceive unmet consumer needs	F/S/A
35. To look for products that provides real benefit	F/S/A
36. To seize high-quality business opportunities	F/S/A
37. To maximize results in resource allocation	F/S/A
38. To see the big picture	C/L/U
39. To tolerate ambiguity	E/S-L/U

Source: [*Kononiuk et al.*, 2017].

Table 3. **The General Algorithm and Example of the Process of Matching beFORE Competences with Corresponding O*NET Database Competences**

beFORE competences	Explanation	Corresponding O*NET database competences
beFORE competences: 01a, 02b, 02a, 02b, 06, 16, 27	Matching beFORE competences with those from O*NET database (example)	O*NET competence A "systems thinking"
beFORE competences: n, n1, n2….	General algorithm applied in the matching process	O*NET competence N
Source: own elaboration.		

for the education processes and environment as factors which have an impact upon knowledge construction. He stresses that self-directed processes and self-guidance contribute to more efficient learning. At the same time, he emphasizes that competences are acquired more effectively when the learning process is embedded in a context [*de Haan,* 2010].

Similar expectations of the project target groups regarding the desired competences as indicated in the survey research devoted to needs analysis supported a pedagogical approach that allows shared modules for the three target groups of the project: academics, students, and business people. Nevertheless, the level of foresight knowledge and foresight literacy should be differentiated in order to meet the needs of the target groups as much as possible.

Hence, the authors of the platform decided that its concept should include, on the one hand, an introductory section on foresight issues and foresight literacy and, on the other hand, it should allow for the introduction of increasingly advanced topics and allow for a balance between theoretical knowledge and practical knowledge.

This encouraged the design of a common course structure with an e-learning architecture starting with the basic courses and adding thematic courses covering advanced material.

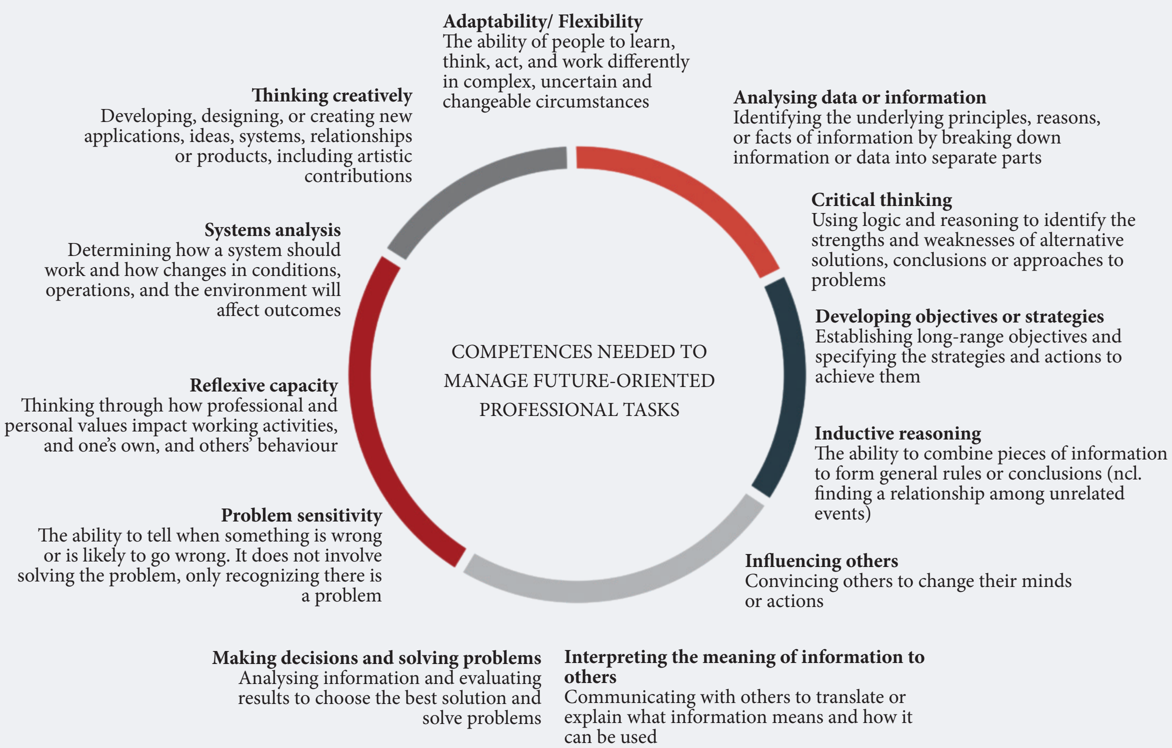
The idea of an e-learning platform benefits from the theories of behaviorism and cognitivism which lay the foundations for the Instructional Systems Design (ISD), which comprises nine learning phases with the aim to motivate the students [*Gagné*,1984; *Merrill*, 2002]. The phases are presented in Figure 4.

Through the implementation of the nine learning events, the newly attained knowledge and the corresponding transmission of competences are continually checked.

The authors of the article emphasize that the accumulation of various educational goals is likely to happen throughout the procedure of accommodating different competences during the acquisition of theory and practice [*Gagne, Merill,* 1990].

The application of nine events within the beFore e-learning platform provided an underlying framework both for the preparation and delivery of the content covering a wide range of educational objectives conveying the twelve general competences in an engaging context for every topic in the training course.

Figure 3. **General Competences**



Source: http://futureoriented.eu/foresight-course/, accessed 18.07.2021.

Table 4. **The Relationship between Specific and General Competences**

Competences	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
1. The ability to define, identify, and analyze trends within the micro- and macroenvironment of a company		√	√		√		√					
2.The ability to find and interpret weak signals of change and disruptions (wild cards and abnormal phenomena)		√	√		√		√				√	√
3. The ability to identify factors influencing the use of strategic foresight by companies		√	√		√							√
4. The ability to define measurable goals to create a preferred future vision for the organization			√	√			√			√	√	√
5. The ability to work in teams	√		√			√	√		√	√		√
6. The ability to possess guerrilla skills to challenge assumptions			√		√	√	√		√	√		√
7. The ability to gather, analyze, process, and interpret data (also using IT tools)		√			√		√			√		
8. The ability to act proactively (autonomous strategic behavior, enterprising spirit)	√		√			√		√		√		√
9. Reflexive capacity	√		√		√		√		√	√		
10. The ability to develop measurement systems to control innovation initiatives and strategic direction		√		√				√				√
11. Coaching skills			√	√	√		√			√		√
12. The ability to communicate internally, in an interdisciplinary manner, and with stakeholders			√				√					
13. The ability to manage projects	√	√	√	√	√	√	√	√	√	√	√	√
14. The ability to develop organizational resilience	√	√	√	√	√	√	√	√	√	√	√	√
15. The ability to run strategic foresight within an organization	√	√	√	√	√	√	√	√	√	√	√	√
16. Systemic thinking					√					√	√	
17. Risk-taking capability	√	√	√	√	√	√		√	√	√	√	√
18. The ability to manage change and uncertainty (also dynamic capability)	√	√	√	√	√	√	√	√	√	√	√	√
19. The ability to build networks both internally and externally						√	√			√		√
20. The ability to deal with complexity	√	√	√	√	√		√	√	√	√	√	√
21. Understanding the dangers of efficiency			√							√		
22. The ability to develop and implement strategies	√	√	√	√	√	√	√	√	√	√	√	√
23. Time competence (time-organizing skills, utilizing real-time, making optimal use of the diversities of time, appreciation of slow life, developing futures thinking, and futures consciousness)		√	√					√		√		√
24. The ability to think out of the box	√		√							√		√
25. The ability to transform new ideas into business practices	√	√	√			√	√			√		√
26. Capacity for design thinking	√	√	√	√	√		√	√	√	√	√	√
27. The ability to implement the scenario approach within an organization	√	√	√	√	√		√		√	√	√	√
28. The ability to create an organizational vision (both collective and individual)	√	√	√	√	√	√	√		√	√	√	√
29. The ability to identify goods or services people want		√	√	√	√	√		√	√	√	√	√
30. Accepting incompleteness of knowledge			√						√	√	√	√
31. Non-linear thinking	√		√							√		√
32. The ability to apply various future studies' methodologies	√	√	√	√	√	√	√	√	√	√	√	√
33. The ability to implement selected methods of technology management (technology assessment, technology mapping, technology life cycle, prioritization, technology audit, and roadmapping)		√	√	√	√	√	√	√	√	√	√	√
34. The ability to perceive unmet consumer needs	√	√	√	√	√		√	√	√	√	√	√
35. The ability to look for products that provide real benefit		√	√	√	√	√	√	√	√	√	√	√
36. Seizing high-quality business opportunities		√	√	√	√		√	√	√	√	√	√
37. Maximizing results in resource allocation	√	√	√							√	√	√
38. Seeing the big picture		√	√		√				√	√	√	√
39. Tolerance of ambiguity	√	√	√		√		√		√	√	√	√

Note: I — Adaptability/Flexibility; II — Analyzing data or information; III — Critical thinking; IV — Developing objectives or strategies; V — Inductive reasoning; VI — Influencing others; VII — Interpreting the meaning of information and conveying it to others; VIII — Making decisions and solving problems; IX — Problem sensitivity; X — Reflexive capacity; XI — Systems analysis; XII — Thinking creatively

Source: own elaboration.

Table 5. **Comparison of the Rankings of Competences Needed in the Present and the Future to Manage Future-Oriented Tasks Combined with the Need for Improvement Both in the Present and Future**

No	Importance and need for improvement		
	In the Present (Q1-Q2 Average)	**In the Future (Q5-Q6 Average)**	**Average of the Present and the Future (Q1-Q2 and Q5-Q6 Average)**
1	Critical Thinking	Adaptability/Flexibility	Adaptability/Flexibility
2	Adaptability/Flexibility	Critical Thinking	Critical Thinking
3	Thinking Creatively	Thinking Creatively	Thinking Creatively
4	Analyzing Data or Information	Developing Objectives and Strategies	Analyzing Data or Information
5	Developing Objectives and Strategies	Influencing Others	Developing Objectives and Strategies
6	Making Decisions and Solving Problems	Making Decisions and Solving Problems	Making Decisions and Solving Problems

Source: own elaboration.

In developing the course, the authors followed Snelbecker's suggestion that the content presented in practice-based learning should create value for the specific situation in which the learning takes place [*Snelbecker,* 1983] (cited by [*Ertmer, Newby,* 2013, p. 8]).

The Architecture and Content of the E-Learning Platform

Further on, the learning objectives were formulated to meet the needs of the target groups and convey the twelve competences needed to become futures literate and attain knowledge in foresight. The following are examples from a list that was the result of an internal exercise to collect and cluster all relevant learning objectives aimed at acquiring knowledge in foresight and futures studies. In the process, topics from foresight and futures studies as well as entrepreneurial aspects were considered and evaluated (Table 6). The resulting training material is intended to encourage active engagement with the content and to illustrate it with practical examples.

The framework of the platform was a superordinate division organizing the content into a total of seven modules from fundamental principles to specializing in futures thinking. Though the recommendation to the learner is to follow the platform's logic, the courses' modules can be entered at any stage offering the learners the flexibility to create a highly individualized learning experience.

The first four modules – "Futures Basic Course" (FBC) – form a unit to introduce the foundation of futures studies such as definitions, perceptions of future images and developments, systems thinking as well as well-known methods used in the field. The modules of the "Futures Advanced Course" (FAC) correspond to the target group differences as defined in the process of the project through the survey (Figure 5).

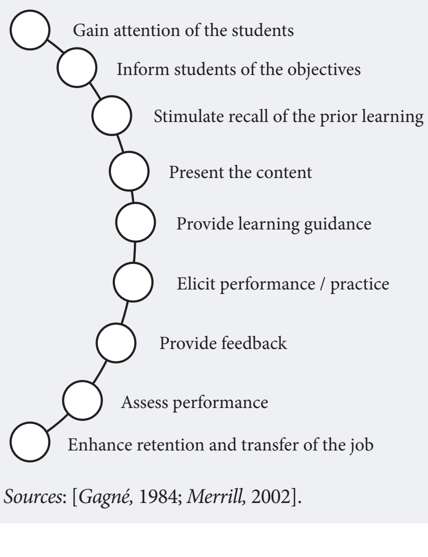
All modules are thematically set up and divided into lessons which consist of topics representing a self-contained learning unit readily available according to the learner's interest. Thus, the individual can acquire the contents of a module or a lesson with selected topics according to their level of knowledge or can repeat and deepen existing knowledge. Students are empowered to determine the course of their personal learning journey by choosing the content at their discretion. Directions are given through examples of learning paths offered on the platform.[8]

The uniqueness of the course is manifested by its flexibility in choosing the learning paths and by introducing in one place a great variety of subjects that deal with the issues of foresight and futures literacy. The course topics are not only about the theory and practice of future studies. The course also deals with issues related to entrepreneurship, in relation to which, in the opinion of the authors, foresight studies form a supportive role. To the authors' knowledge, the course offered is currently the most extensive free, open access course offered in the field of foresight and futures literacy.

Set up and Challenges of the Educational Offer

For learners who have no previous knowledge in this area, it is recommended that they work through most of the topics of the first four modules of the FBC. These modules cover all relevant topics in the areas of future orientation, futures studies, and corporate foresight. The FBC introduces the field and intends to generate interest in topics related to futures and foresight and create a knowledge base for all learners. Since an important aspect of futures literacy is to reflect on and understand the concept of futures [*Bell,* 1997], the first module in particular focuses on the competences of adaptability/flexibility, critical thinking, and reflexive capacity.

Figure 4. **Nine Learning Phases**



Sources: [*Gagné,* 1984; *Merrill,* 2002].

[8] http://futureoriented.eu/foresight-course/, accessed 22.06.2021.

Table 6. **Exemplary Learning Objectives and Topics in Relation to the Twelve Competences for Future-Oriented Entrepreneurs**

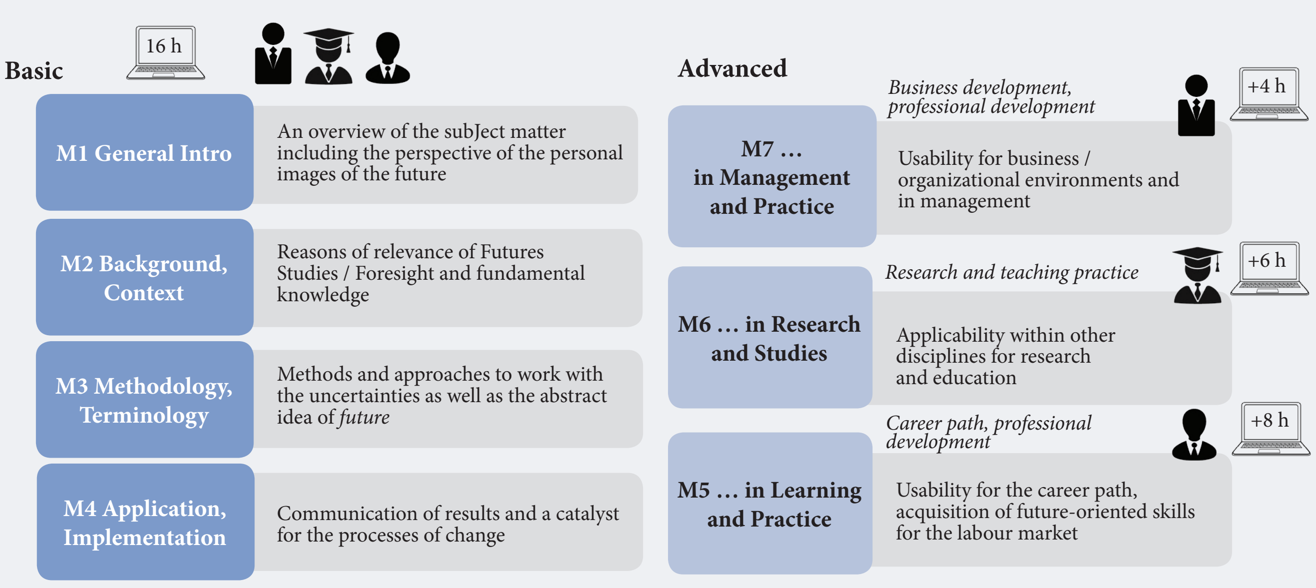
Module/ Lesson/Topic	Learning objective	Content (short description)	Competences
M1/L2/T1,3,4 M4/L3/T1-3	Be able to think strategically on a long-term basis by using the most well-known tools in entrepreneurship design and innovation management.	Explanation of the differences between normative and explorative scenarios; Time makes a difference	Critical thinking Developing Objectives and Strategies Problem Sensitivity
M2/L1/T1-3	Be able to monitor and evaluate changes in the external environment, discover new directions and move between megatrends and trends.	Differences between uncertainty and risk	Analyzing Data or Information Adaptability/ Flexibility Making Decisions and Solving Problems
M6/L4/T1-4	Be able to use methods of futures studies in their research as well as practical templates to convey the ideas to students	In the sense of FS becoming an accompanying social science course. Toolbox for academia to be used with their students to reflect on how their work or their future work or the results of it affect technology, competition, ecology, society, and have an impact.	Adaptability/Flexibility Thinking Creatively Reflexive Capacity
M7/L1/T1,2 M5/L2/T1,2	Evaluate and be able to use selected foresight methods in practice	Real-life examples concerning the scenario method, Delphi method, roadmapping method applications for foresight studies	Analyzing data or information Developing Objectives and Strategies System Analysis

Source: own elaboration.

For example, in the beFORE educational offer, participants are asked in Module 1 Lesson 1 to think of their personal ideas of the future. They receive thought provoking questions and are encouraged to use a learning diary. Later in this module, students are introduced to the concept of multiple futures as well as organizational and global futures. To reinforce the knowledge in the lessons, the learner will do assignments and quizzes to practice the theory. Table 7 provides an overview of content of the FBC and FAC.

The flexible structure of the platform and the opportunity to acquire knowledge independently takes into account the different interests, life circumstances, levels of experience, and time contingents of learners. At the same time, it requires a high degree of self-assessment and intrinsic motivation for the subject. The first iteration through a pilot launch of the e-learning platform was well received by representatives of all three target groups in all four project partner countries. A certain inconsistency of the training material was criticized. This was taken up in the phase of qualitative upgrading and the contents were revised as a result. The platform can be understood as a well-crafted prototype, which focuses on content and uses simpler interactive methods such as the learning diary. Furthermore, the e-learning platform is without instructional support and therefore requires the autodidactic abilities of all learners. In particular, the lack of support and the prerequisite of personal motivation can lead to the discontinuation of online-based learning [*Johnson, Brown*, 2017]. The project ended in December 2019, but the e-learning platform

Figure 5. **Course Architecture of the beFORE e-Learning Platform**



Source: own elaboration.

Table 7. **Brief Overview of the Course Modules**

Module	Description / aim
Basic modules	
Module 1. General introduction to futures studies	• An introduction to the concept of the future and futures; • An overview of the field of futures research and strategic foresight; • Insight into the different perspectives on the future
Module 2. Background and relevance of foresight	• A first overview of areas of application; • Explanation of basic knowledge from the field of system theory relevant for foresight work
Module 3. Methodology and terminology in futures studies	• An overview of the methods and tools needed to work with the abstract notions of future / uncertainty; • putting concepts into context
Module 4. Fields of application of futures studies in the economy	• Introduction to specific methods; communication and handling of results; • Application of the results based on a design process
Advanced modules	
Module 5 (for students)	Usability for future career paths, acquisition of skills relevant for a future job market
Module 6 (for academics)	Possible use within their discipline in research and teaching
Module 7 (for entrepreneurs)	The applications for businesses and the organizational environment in management as well as for start-ups

Souce: own elaboration.

continues to be accessible in accordance with the open access principle. The challenges remain that there is no immediate learning support, facilitation, or monitoring of learning success. In future iterations, a forum for knowledge exchange and further interactivity may be needed; for example, online coaching services. Nonetheless, the response to the platform has been positive and is available for use by educators in entrepreneurship, management, or futures studies.

Summary and Discussion

The biggest challenge when developing the course was related to the fulfillment of learning needs (related to futures thinking) of the three different target groups that the course was supposed to cater to: the academics and students and the business professionals (any working individual interested in enhancing future-orientated skills).

We managed to do so by:

- Successfully identifying key competences – sought-for by the target groups –which address the thematic gaps in the entrepreneurial education and business/professional practice related to future-orientation and futures literacy;
- Efficiently translating the missing competences into the curriculum of an open access online course composed of self-standing basic and advanced course modules as well as three recommended learning paths for each target group.

Based on the undertaken literature review and the results of our own research, we highlight how those methodologies, concepts, and methods in the futures studies field fill the competence gap, complement entrepreneurship education, and enrich business practice. In particular, these concepts help to shift focus from economic models of financial evaluation [*Ratcliffe, Ratcliffe*, 2015], they facilitate the process to go beyond rational forecasting and managerial economics [*Fontela,* 2006] that result in cultivating an engineering management mindset [*Hurst*, 2014]. We agree that the inclusion of foresight and futures literacy topics and approaches into the learning journeys of students and professionals expands their perception of the concepts of incidental externalities and business durability [*Ratcliffe, Ratcliffe,* 2015], enhances their sustainable global thinking, systems thinking [*Postma, Yeoman,* 2021], and cross-disciplinary thinking. It also deepens the discussion about humanistic and scientific trends [*Roos*, 2014].

We believe that awareness of the possibility of futures analysis and the context that enables the development of future-oriented competences are extremely important. The results presented by [*Jafari-Sadeghi et al.,* 2019] show that higher levels of education or knowledge in a country enhances foresight competencies.

Based on undertaken research, we illustrate how general concepts and methods of the futures studies and foresight field enrich and complement business and entrepreneurship education and enhance specific competences (Table 8).

The proposed changes in entrepreneurship curricula and business practice – toward which our research contributes – should allow us to "develop new understandings of how intuition and reason can work together especially in the service of creativity and innovation" [*Hurst,* 2014]. The aim of such a transformation of entrepreneurship education would be "to enhance the dominant paradigm of strategy building among organisations, which rests on the classical, rational approach of deliberate planning with more emergent and creative ways" [*van der Laan*, 2010].

The above is complemented by the World Bank study on Entrepreneurship Education and Training Programs around the world, which reports that entrepreneurs cite mindsets and skills as a potential constraint to entrepreneurial opportunity and success [*Valerio et al.,* 2014, pp. 20-21]. Therefore, the main objective of our research was to prototype an open online educational platform that would help individuals to become more futures literate.

Prior to the design of the course structure, we had to agree upon a pedagogical strategy and the didactical approach. In educational sciences, they are the foundation of understanding how students acquire knowledge and have been applied in designing learning experiences. Starting from the premise that although technology and media for learning is changing various ways of how to obtain knowledge, how people learn

Table 8. **Augmentation of Business and Entrepreneurship Education with Futures Studies Education Offer**

What is being taught		*What is missing*
Business management education	**Entrepreneurship education and training**	**Futures Studies and Strategic Foresight**
Corporate management	Entrepreneur Development	Sustainable development
Leadership and Organizational Theory Corporate Finance and Risk Management Managerial Economics	Entrepreneurship Theory and principles Financial literacy Entrepreneurship awareness and socio-emotional skills	Organizational foresight theory and methods Systems analysis Societal / Environmental impacts of innovations
Acquired competences relevant for **Business and professional practice**		
Strategic planning General business skills (i.e. sales, marketing, bookkeeping)		Long-term orientation Futures thinking/ Futures Literacy

Source: own elaboration based on [*Valerio et al.*, p. 22; *van der Laan,* 2010; *Dannenberg, Grapentin,* 2016; *Heinonen, Ruotsalainen*, 2012].

has not tremendously changed [*Ertmer, Newby,* 2013]; we focused on the future-oriented competences, which became the foundation in generating the content for the e-learning platform.

Limitations and Further Research

In the context of the undertaken research, it needs to be underlined that it was not our aim to develop or update the occupational standards of a futurist, researcher, or an entrepreneur as such. Neither was the online futures literacy course, which was created as a result of our research, to provide students, researchers, or entrepreneurs with the full qualifications of a futurist. On the other hand, the research team aimed to identify the gaps within the competences of the aforementioned target groups that relate to future analysis and design an online course, which would address these gaps. From this perspective our research aim – of equipping students, teachers, researchers, or entrepreneurs with additional foresight-like skills that would complement their main professional competences – was met.

The results obtained contribute to the discussion on pedagogical strategies that might be undertaken in the area of futures literacy and also set a good e-learning practice example that could serve as a guide in entrepreneurship and futures studies education to absorb methods and the competences for a futures literate mindset.

The main learning objective, which was pursued rested on the shared understanding that "… the diffusion of futures literacy, is one way of improving the capacity of individuals and organisations to: a) detect and give meaning to discontinuity, and b) thereby become more capable of initiating learning processes" [*Miller,* 2015].

Therefore, some of the suggested topics for further research could refer to the fundamental issues of learning processes:

- *Motivation, learning behavior, and the associated question of learning success.* Proposed research questions could be: What impacts the effectiveness of the individual modules, lessons, and topics as individual learning items (single topics) and as a whole? And by which target group? How does one increase the effectiveness, usability, and enjoyability for learners?
- *Thematic-orientation and topics covered, and effectiveness of practical exercises embedded in the course.* Proposed research questions could be: How effective are the individual modules, lessons, and topics for learners in terms of the enhancement of their capability of futures literacy? What are the recommended assessment criteria?
- *Use and impact of the materials at organizations.* Proposed research questions could be: Whether and to what extent the learning platform could support the advancement and evaluation of organizational future orientation? What additional interactive tools would allow for collective organizational learning?

To sum up, uncertainty on a global scale caused by the Covid-19 pandemic has only accelerated changes and developments of the digital economy and brought further advancements in technology. It certainly has triggered an enormous learning and re-learning imperative for all. It has contributed to the growth in demand for new entrepreneurship skills and resulted in greater demand for competences – such as futures thinking – that boost resilience. In the sustained adverse external conditions, we can assume that the demand for high-quality yet flexible educational offers will increase dramatically. We hope that our open online educational resources, at least in part, will help individuals to learn to navigate uncertainty.

The research was carried out within the beFORE – Becoming Future-Oriented Entrepreneurs in universities and companies Project funded by European Commission Erasmus + Programme – Key Action 2; Knowledge Alliances - Agreement n. 2016 - 2858 / 001 - 001 Project n. 515842-EPP-1-2016-1-PL-EPPKA2-KA. The preparation of the article on the part of Bialystok University of Technology was carried out within the WZ/WIZ-INZ/1/2019 project and was financed using Ministry of Science and Higher Education funds.

References

Alsan A. (2008) Not with a bang, but a Blink. *The Futurist*, 42(1), 4+. https://link.gale.com/apps/doc/A172911390/ITOF?u=fub&sid=ITOF&xid=3eecb5e8, accessed 15.06.2021

Andriopoulos C., Gotsi M. (2006) Probing the future: Mobilising foresight in multiple-product innovation firms. *Futures* 38 (1), 50–66. https://doi.org/10.1016/j.futures.2005.04.003

Arpentieva M.R., Gorelova I.V., Kassymova K.G., Lavrinenko S.V., Shumova K.A., Malinichev D.M., Simonov V.L., Kosov A.V., Garbuzova G.V., Stepanova O.P. (2020) Human Resource Management and Dynamic Capabilities of Educational Enterprises: Psychological, Social and Economic Aspects. *Bulletin of National Academy of Sciences of the Republic of Kazakhstan*, 1(38), 242–254.

Baškarada S., Shrimpton D., Ng S. (2016) Learning through foresight. *Foresight,* 18(4), 414–433. https://doi.org/10.1108/FS-09-2015-0045.
beFORE (2018) *Future-oriented individuals: Lessons learned from a competence survey* (WP2 report). http://futureoriented.eu/wp-content/uploads/wp2f.pdf, accessed 21.05.2021.
Begley C.M. (1996) Using triangulation in nursing research. *Journal of Advanced Nursing,* 24(1), 122–128. https://doi.org/10.1046/j.1365-2648.1996.15217.x
Bell W. (1997) The purposes of futures studies. *The Futurist,* 31(6), 42–45.
Bell W. (2009) *Foundations of Futures Studies. History, Purpose, and Knowledge Human Science for a New Era* (vol. 1), New Brunswick (U.S.) and London (UK): Transaction Publishers.
Bridge S. (2017) Is "entrepreneurship" the problem in entrepreneurship education? *Education+ Training,* 59(7–8), 740–750. https://doi.org/10.1108/ET-02-2016-0037
Chiu F.-C. (2012) Fit between future thinking and future orientation on creative imagination. *Thinking Skills and Creativity,* 7(3), pp. 234-244. http://dx.doi.org/10.1016/j.tsc.2012.05.002
Clark B.R. (2003) Sustaining Change in Universities: Continuities in Case Studies and Concepts. *Tertiary Education and Management*, 9(2), 99–116. https://doi.org/10.1080/13583883.2003.9967096
Clark R.C., Mayer R.E. (2016) *E-learning and the science of instruction: Proven guidelines for consumers and designers of multimedia learning.* Hoboken, NJ: John Wiley & Sons, Inc. DOI:10.1002/9781119239086
Cuhls K., Johnston R. (2008) Corporate foresight. In: *Future-Oriented Technology Analysis. Strategic intelligence for an innovative economy* (eds. C. Cagnin, M. Keenan, R. Johnston, F. Scapolo, R. Barre), Heidelberg, Dordrecht, London, New York: Springer, pp. 103–114. https://doi.org/10.1007/978-3-540-68811-2_8
Dannenberg S., Grapentin T. (2016) Education for Sustainable Development – Learning for Transformation. The Example of Germany. *Journal of Futures Studies,* (20)3, 7–20. DOI:10.6531/JFS.2016.20(3).A7
De Haan G. (2010) The development of ESD-related competencies in supportive institutional frameworks. *International Review of Education / Internationale Zeitschrift Für Erziehungswissenschaft / Revue Internationale De L'Education,* 56(2–3), 315–328. https://www.jstor.org/stable/40928675
Denzin N.K. (1989) *The research act: A theoretical introduction to sociological methods* (3rd ed.), New York: Routledge.
Ejdys J., Gudanowska A., Halicka K., Kononiuk A., Magruk A., Nazarko J., Nazarko Ł., Szpilko D., Widelska U. (2019) Foresight in Higher Education Institutions: Evidence from Poland. *Foresight and STI Governance*, 13(1), 77–89. DOI: 10.17323/2500-2597.2019.1.77.89
Ertmer P.A., Newby T.J. (2013) Behaviorism, Cognitivism, Constructivism: Comparing Critical Features from an Instructional Design Perspective. *Performance Improvement Quarterly,* 26(2), 43–71. DOI: 10.1002/piq.21143.
ETF (2017) *Skills Foresight: Making Sense of Emerging Labour Market Trends*, Turin: European Training Foundation.
European Commission (2012) *European Commission, Entrepreneurship 2020 Action Plan – Reigniting the Entrepreneurial Spirit in Europe* (COM (2012) 795 final), Brussels: European Commission.
Fareri S., Fantoni G., Chiarello F., Coli E., Binda A. (2020) Estimating Industry 4.0 impact on job profiles and skills using text mining. *Computers in Industry,* 118, 103222. https://doi.org/10.1016/j.compind.2020.103222
Fontela E., Guzmán J., Pérez M., Santos F. J. (2006) The art of entrepreneurial Foresight. *Foresight,* 8(6), 3–13. https://doi.org/10.1108/14636680610712496
Fuller T., Warren L., Argyle P. (2008) Sustaining entrepreneurial business: A complexity perspective on processes that produce emergent practice. *International Entrepreneurship and Management Journal*, 4(1), 1–17. https://doi.org/10.1007/s11365-007-0047-y
Gagné R.M. (1984) Learning outcomes and their effects: Useful categories of human performance. *American Psychologist,* 39(4), 377–385. https://doi.org/10.1037/0003-066X.39.4.377
Gagné R.M., Merrill M.D. (1990) Integrative Goals for Instructional Design. *Educational Technology, Research and Development,* 38(1), 23–30. https://doi.org/10.1007/BF02298245
Gheorghiua R., Andreescu L., Curaj A. (2016) A foresight toolkit for smart specialization and entrepreneurial discovery. *Futures,* 80, 33–44. https://doi.org/10.1016/j.futures.2016.04.001
Gidley J.M. (2017) *Very Short Introductions*, Oxford: Oxford University Press.
Grim T. (2009) Foresight Maturity Model (FMM): Achieving Best Practices in the Foresight Field. *Journal of Futures Studies,* 13(4), 69–79.
Gudanowska A., Kononiuk A., Dębkowska K. (2020) The application of cluster analysis for the selection of key competences of future-oriented entrepreneurs. *Inzinerie Ekonomika-Engineering Economics*, 31(5), 565–574.
Heinonen S., Ruotsalainen J. (2012) Toward the age of neo-entrepreneurs. *World Futures Review*, 4(2), 123–133. DOI: 10.1177/194675671200400216.
Hiltunen E. (2013) *Foresight and Innovation. How Companies are Coping with the Future*, London: Palgrave MacMillan.
Hines A., Gary J., Daheim C., van der Laan L. (2017) Building foresight capacity: Toward a foresight competency model. *World Futures Review*, 9(3), 123–141. https://doi.org/10.1177%2F1946756717715637
Hurst D. (2014) *Is Management Due for a Renaissance? Harvard Business Review*, 30.05.2014. https://hbr.org/2014/05/is-management-due-for-a-renaissance, accessed 29.05.2020.
Inayatullah S. (2008) Six pillars: Futures thinking for transforming. *Foresight,* 10(1), 4–21. https://doi.org/10.1108/14636680810855991
Jafari-Sadeghi V., Kimiagari S., Biancone P.P. (2020) Level of education and knowledge, foresight Competency and international entrepreneurship. *European Business Review*, 32(1), 46–68. DOI:10.1108/EBR-05-2018-0098
Jain R.K. (2011) Entrepreneurial Competencies: A Meta-analysis and Comprehensive Conceptualization for Future Research. *Vision,* 15(2), 127–152. https://doi.org/10.1177/097226291101500205
Johnson R.D., Brown K.G. (2017) E-Learning. In: *The Wiley Blackwell Handbook of the Psychology of the Internet at Work* (eds. G. Hertel, D.L. Stone, R.D. Johnson, J. Passmore), Hoboken, NJ: Wiley, pp. 369–400. https://psycnet.apa.org/doi/10.1002/9781119256151.ch17
Jones N., O'Brien M., Ryan T. (2018) Representation of future generations in United Kingdom policy-making. *Futures*, 102, 153–163. https://doi.org/10.1016/j.futures.2018.01.007
Jonsen K., Jehn K.A. (2009) Using triangulation to validate themes in qualitative studies. *Qualitative Research in Organisations and Management,* 4(2), 123–150. https://doi.org/10.1108/17465640910978391
Kaivo-oja J.R.L., Lauraeus I.T. (2018) The VUCA approach as a solution concept to corporate foresight challenges and global technological disruption. *Foresight*, 20(1), 27–49. https://doi.org/10.1108/FS-06-2017-0022
Keller K.C. (2013) Nachhaltige Innovationen gestalten. In: *Zukunftsforschung im Praxistest. Schriftenreihe: Zukunft und Forschung* (eds. R. Popp, A. Zweck), Bd. 3, Berlin, Heidelberg: Springer, pp. 385–407. https://doi.org/10.1007/978-3-531-19837-8_16
Knight F.H. (1921) Cost of production and price over long and short periods. *Journal of Political Economy,* 29(4), 304–335. https://doi.org/10.1086/253349
Kononiuk A., Gudanowska A., Magruk A., Sacio-Szymańska A., Fantoni G., Trivelli L., Ollenburg S. (2017) *Becoming Future-Oriented Entrepreneurs in Universities and Companies* (WP1 report), Brussels: European Commission. http://futureoriented.eu/wp-content/uploads/wp1f.pdf, accessed 18.01.2021.
Kononiuk A., Pająk A., Gudanowska A., Magruk A., Rollnik-Sadowska E., Sacio-Szymańska A. (2020) Foresight for Career Development. *Foresight and STI Governance* 14(2), 88–104.
Kreibich R., Oertel B., Wölk M. (2011) *Futures Studies and Future-Oriented Technology Analysis Principles, Methodology and Research* (HIIG Discussion Paper Series Discussion Paper 2012-05). Paper presented for the 1st Berlin Symposium on Internet and Society, October 25–27. DOI:10.2139/ssrn.2094215

Lefebvre C., Glanville J., Wieland L.S., Coles B., Weightman A.L. (2013) Methodological developments in searching for studies for systematic reviews: Past, present and future? *Systematic Reviews*, 2(1),78. DOI: 10.1186/2046-4053-2-78.

Lewrick M., Maktoba O., Raeside R., Sailer K. (2010) Education for Entrepreneurship and Innovation: Management Capabilities for Sustainable Growth and Success. *World Journal of Entrepreneurship, Management and Sustainable Development*, 6(1–2), 1-18. http://dx.doi.org/10.1108/20425961201000001

Martin R.L. (2019) The high price of efficiency. *Harvard Business Review*, January–February, 42–55. https://hbr.org/2019/01/the-high-price-of-efficiency, accessed 28.06.2021.

Merrill M.D. (2002) First principles of instruction. *Educational Technology Research and Development,* 50, 43–59. https://doi.org/10.1007/BF02505024

Miller R. (2015) Learning, the Future, and Complexity. An Essay on the Emergence of Futures Literacy. *European Journal of Education,* 50(4), 513–523. https://doi.org/10.1111/ejed.12157

Miller R. (2018) *Transforming the future: Anticipation in the 21st century,* New York: Routledge. https://doi.org/10.4324/9781351048002

Morris M.H., Webb J.W., Fu J., Singhal S. (2013) A competency-based perspective on entrepreneurship education: Conceptual and empirical insights. *Journal of Small Business Management,* 51(3), 352–369. https://doi.org/10.1111/jsbm.12023

Nanus B. (1977) Management training in futures concepts. *Futures,* 9(3), 194–204. https://doi.org/10.1016/0016-3287(77)90033-7

Postma A., Yeoman S. (2021) A systems perspective as a tool to understand disruption in travel and tourism. *Journal of Tourism Futures*, 7(1), 67–77.

Ratcliffe J., Ratcliffe L. (2015) Anticipatory leadership and strategic foresight: Five 'linked literacies'. *Journal of Futures Studies,* 20, pp. 1–18.

Rieckmann M. (2011) Future-oriented higher education: Which key competencies should be fostered through university teaching and learning? *Futures,* 44, 127–135. https://doi.org/10.1016/j.futures.2011.09.005

Rohrbeck R. (2011) *Corporate foresight: Towards a maturity model for the future orientation of a firm*, Heidelberg: Physica-Verlag. https://doi.org/10.1007/978-3-7908-2626-5

Roos J. (2014) The Renaissance We Need In Business Education. *Harvard Business Review,* July. https://hbr.org/2014/07/the-renaissance-we-need-in-business-education/, accessed 24.06.2020.

Rudzinski C.V., Uerz G. (2014) Volkswagen: Open Foresight at the Front End of Research Innovation. In: *Management of the Fuzzy Front End of Innovation* (eds. O. Gassmann, F. Schweitzer), Heildelberg, Dordrecht, London, New York: Springer, pp. 295–299.

Sajwani Z.S., Hazzam J., Lahrech A., Alnuaimi M. (2021) A strategy tripod perspective on merger effectiveness in the higher education industry: The mediating role of future foresight. *International Journal of Educational Management*, 35(5), 925–942.

Schumpeter J.A. (1934) *The Theory of Economic Development*, Cambridge, MA: Harvard University Press.

Snelbecker G. (1983) *Learning theory, instructional theory, and psychoeducational design,* New York: McGraw-Hill.

Song A., Hormuth W. (2013) Die BASF Future Business GmbH. Vom Trendscouting zum Aufbau neuer Geschäftsfelder. In: *Zukunftsforschung im Praxistest. Schriftenreihe: Zukunft und Forschung* (eds. R. Popp, A. Zweck), Bd. 3, Berlin, Heidelberg: Springer, pp. 181–194.

Stordy P. (2015) Taxonomy of literacies. *Journal of Documentation*, 71(3), 456–476. https://doi.org/10.1108/JD-10-2013-0128

Suleiman A., Abahre J. (2020) Essential competencies for engineers from the perspective of fresh graduates. *Engineering Management in Production and Services,* 12(1), 70–79. DOI: 10.2478/emj-2020-0006.

Thomassen M.L., Middleton K.W., Ramsgaard M.B., Neergaard H., Warren L. (2019) Conceptualizing context in entrepreneurship education: A literature review. *International Journal of Entrepreneurial Behavior & Research,* 26(5), 863–886. https://doi.org/10.1108/IJEBR-04-2018-0258

Valerio A., Parton B., Robb A. (2014) *Entrepreneurship Education and Training Programs around the World: Dimensions for Success*, Washington, DC: World Bank. DOI: 10.1596/978-1-4648-0202.

van Atta R.H., Lippitz M.J., Bovey R.L., Dubin R.D., Blazek S.L. (2011) *Commercial Industry Research & Development Management Best Practices*, Alexandria, VA: Institute for Defense Analysis.

van der Heijden K. (2000) *Scenarios: The Art of Strategic Conversation* (2nd ed.), Hoboken, NJ: Wiley.

van der Laan L. (2010) *Foresight competence and the strategic thinking of strategy-level leaders*. Toowoomba: University of Southern Queensland.

van der Laan L., Erwee R. (2012) Foresight styles assessment: A valid and reliable measure of dimensions of foresight competence? *Foresight,* 14(5), 374–386. https://doi.org/10.1108/14636681211269860

Volpentesta A.P., Felicetti A.M. (2011) Competence Mapping through Analysing Research Papers of a Scientific Community. In: *Technological Innovation for Sustainability*. *DoCEIS 2011. IFIP Advances in Information and Communication Technology* (ed. L.M. Camarinha-Matos), vol. 349. Springer, Berlin, Heidelberg. https://doi.org/10. 1007/978-3-642-19170-1_4

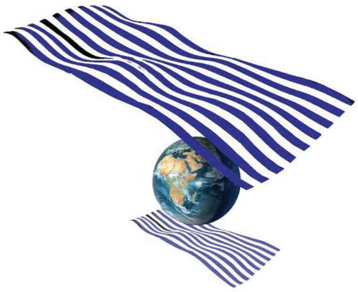
Walras L. (1954) *Elements of Pure Economics*, London: Allen & Unwin.

Weiner E., Brown A. (2008) *FutureThink: How to Think Clearly in a Time of Change*, New York: FT Press.

Wippel N. (2014) *Multinational strategic foresight of environmental trends in the automobile industry using internal resources*, Bremen: University of Bremen.

Xu Y., Yeh C.-H. (2012) An integrated approach to evaluation and planning of best practices. *Omega,* 40(1), 65–78.

ISSN 1995-459X



Website

Download on the App Store

GET IT ON Google Play