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STRATEGIES

INNOVATION

Exploring the Top-Priority Innovation Types and Their Reasons

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Abstract

This is a foresight study to explore the top priorities of innovation types and the reasons behind them with respect to artificial intelligence (AI), big data, and the Internet of Things (IoT). This study set up two research strategies. One of the research strategies is to make the research design and methods fit with this study's intellectual queries. Another strategy is to use the triangulations of method, analysis, data source, and researcher. This study selected expert panels, the Delphi technique, and interviews. In the collection of the qualitative and quantitative data from 23 experts through the Delphi surveys, it organized respectively the qualitative and quantitative data analysis. This study conducted the two main data analyses – Delphi results and interview data.

Service innovation of AI and process innovation of IoT are chosen as a top-priority-innovation type. Marketing innovation of big data, as non-technological innovation, is selected as a top-priority innovation type. Through the interviews with 17 experts, for each of the pairs, all the experts said that the three technologies can have greater technological capabilities going beyond the existing capacities of relevant technologies. AI as hyper-intelligence can help to provide more customized or sophisticated converging offerings, the regulation of various non-standardized services and service provisions through the interaction between AI and customers or employees. The technological capacity of big data and the need of customer preferences can lead marketing innovation. IoT can create the new or improved process of the manufacturing, production, and supply chain areas through hyper-connectivity in terms of quality, quantity, speed, and coverage of information.

Keywords: top-priorities; innovation types; technological performance; reasons; artificial intelligence; big data; Internet of Things

Paper type: Research Article

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Introduction

This is a foresight study to explore the top priorities of innovation types and their reasons in terms of artificial intelligence (AI), big data, and the Internet of Things (IoT). It uses the eight-innovation types relevant to the new wave of industrial revolution (Kim, Kang, 2019). Emerging technologies such as AI, big data and IoT have revolutionary characteristics (Kang et al., 2019): AI as a new strong driver shaping the new industrial revolution (Bughin et al., 2017; Cockburn et al., 2018; Kim, 2018; OECD, 2016a, 2017); the era of the big data revolution (Erevelles et al., 2016; Gobble, 2013; OECD, 2015); and IoT as a new revolutionary technology (OECD, 2016b; Porter, Heppelmann, 2014). It was noted that these three technologies could have huge impacts upon each firm's activities, industries, and the economy and society. In the phenomena of blurring boundaries between manufacturing and service areas (Kim, 2018; Miles, 2016; Santamaria et al., 2012), a firm's innovation on each technology will drive or reflect those trends, which draw a part of the picture of the new industrial revolution (Kim, Kang, 2019; Schwab, 2017).

Since the emergence of information and communication technology (ICT), there has been rapid growth of service innovations, managerial innovations, and business model innovations (Birkinshaw et al. 2008; Ettlie, 2000; Miles, 2016; Mowery, Bruland, 2005; Spieth et al., 2014). It can be expected that those innovations will continue to grow in the three technologies within the framework of the new industrial revolution (Erevelles et al., 2016; Gobble, 2013; Li, 2018; Ransbotham et al., 2017). While there have been various studies on innovation types regarding AI, big data, and IoT (Bughin et al., 2017; Cockburn et al., 2018; Erevelles et al., 2016; Gobble, 2013; Huang, Rust, 2018; Kim, Kang, 2019; Makridakis, 2017; Porter, Heppelmann, 2014; Yu et al., 2016) in a systematic manner, the discrepant impact of three technologies on innovation types have been insufficiently examined in the literature on this new wave of industrial revolution. Generally, the new emerging innovation or dominant innovation types of each technology, historically driving the phenomena of industrial revolution, have been demonstrated (Feldman, 2002; Freeman, Locua, 2001; Kang et al., 2019; Mowery, Bruland, 2005; Rindfleisch et al., 2017). By using Delphi surveys, this study attempts to explore different top-priority innovation types for each technology. This can give us some important theoretical and practical insights into a firm's innovation behaviors regarding these three technologies as part of the new phenomena of the industrial revolution. Most of all, by exploring the reasons why a top-priority innovation type is selected, this study can search for an explanation for why a top-priority innovation type in terms of each technology was selected. Thus it could be possible to offer us some theoretical insights into firm behavior concerning a specific innovation.

To implement this foresight study, multiple methods are utilized: an expert panel, Delphi surveys, and two different interview methods, after having conducted the literature review and outlining the research questions. Following the explanation of the research methods, this study presents the findings and draws conclusions.

Literature Review and Research Questions

Literature Review

Many studies have attempted to theoretically categorize various firms' innovation activities into innovation types (Abernethy, Utterback, 1978; Birkinshaw et al., 2008; Christensen, 1997; Coombs, Miles, 2000; Damanpour et al., 1989; Davenport, 1993; Ettlie, Reza, 1992; Ettlie, Rosenthal, 2011; Francis, Bessant, 2005; Gault, 2018; Henderson, Clark, 1990; Johnson et al., 2008; Kim, Kang, 2019; Miles, 2007; Nijssen et al., 2006; Tushman, Anderson, 1986; Utterback, 1996). By establishing the new parameters, they are willing to distinguish a new innovation type from the existing innovation categories. A variety of empirical and case studies seek to validate new innovation types. This study endeavours to clarify the literature and illustrate the scope of innovation types. It does not deal with the individual-level or policy-level innovations because it focuses on firm-level innovation activities regarding AI, big data, and IoT. The main directions of existing studies on the classification of innovation types are represented in Table 1. Those studies have proposed the combinative usage of innovation types for a given purpose to understand a firm's innovation activities on the criteria of demarcation. Another approach of an innovation-type study is to use innovation surveys to identify firm innovative behaviors. One of the best examples is the community innovation survey in some European and Asian countries, which is used to measure to which extent innovative activities have been conducted by leveraging (non-) technological innovations from existing innovation studies (Eurostat, 2014, 2016). Many studies used the results of the community innovation survey to understand firms' innovation behavior (Battisti, Stoneman, 2010; Martinez-Ros, Labeaga, 2009; Sirilli, Evangelista, 1998). A variety of innovation types can be suggested according to the diverse parameters set by researchers (Gault, 2018).

Many studies noticed AI, big data, and IoT can be regarded as key technologies in the new wave of the industrial revolution (Cockburn et al., 2018; Kang et al., 2019; OECD, 2015, 2017; Porter, Heppelmann, 2014). In the consideration of these three technologies, this study intends to use eight innovation types relevant to the new wave of the industrial revolution. Kim and Kang (2019) identified eight innovation types through a Delphi survey of the fourth industrial revolution. Thus, this study defined and classified eight-innovation types in three technological dimensions (see Table 2).

Research Questions

Although the existing studies made contributions to understanding some innovation types regarding AI, big data, and IoT, they are not able to explain which innovation types for each technology could be highly pri-

oritized and why top-priority innovation types of each technology are selected. Because AI, big data, and IoT have a revolutionary impact upon firms' activities, examining the top priorities of innovation types in each technology can be important to theoretically explaining and practically capturing a firm's innovative behaviors in the new wave of the industrial revolution. The current studies of innovation types do not fully examine the impacts upon innovation types for each technology. Hence, this study considers different magnitudes of innovation types with respect to AI, big data, and IoT. In the consideration of different priority innovation types for these three technologies, we ask the following:

RQ1: What are the top-priority innovation types for each technology?

By identifying the top priorities of eight innovation types with respect to AI, big data, and IoT, this study tries to understand the reasons why a high priority innovation type is selected. Because the three technologies could drive new phenomena of the industrial revolution (Kang et al., 2019; Kim, Kang, 2018; OECD, 2015, 2017; Schwab, 2017), they could imply a dominant innovation type for each despite still being in the embryonic stage. Regarding the usage of technology, the plausible reasons for an innovation type to be selected as a top-priority for each technology can give us a better theoretical and practical understanding of a firm's innovative behavior. Thus, we pose the following research question:

RQ2: Why was a top-priority innovation type for each technology selected?

Research Methods

Research Design

This study has set up two research strategies regarding the use of multiple methods, particularly in terms of its research questions. One of the research strategies is to make the research design and methods fit with this study's intellectual queries. We selected the expert panels, the Delphi technique, and interviews. The method selection is concerned with the ways to achieve the purpose of this study (Popper, 2008b). At first, the expert panel can provide relevant expertise to answer the intellectual queries (Miles et al., 2016). This study used the expert panel to judge which innovation types to prioritize for each technology. However it may require balanced expertise in terms of technological and industrial differences. Compared to the large-scale surveys or other experiments, targeted expert panels can offer more insightful judgements concerning of top-priority innovation types in term of resource constraints and the maturity of technology development and diffusion. Secondly, the Delphi technique is often used to examine new phenomena such as the industrial revolution (Miles et al., 2016; Kim, Kang, 2019; Kang et al., 2019). It was selected to exploit expert assessments of these innovations in AI, big data, and IoT. Finally, an interview is a guided and purposeful conversation between two or more people (Popper, 2008b). It can be useful to gather knowledge of why top-priority innovation types for each technology were selected.

Another strategy is to use the triangulation technique of method, analysis, data source, and researcher — all of which were adopted in this study. The method triangulation can be considered as a way to complement the weaknesses of each method and to overcome the problems of research bias (Cox, Hassard, 2005). The use of the Delphi technique and interviews to examine top-priority innovation types of each technology can be complemented. Multiple methods in this study intrinsically indicate the use of multiple data sources, such as quantitative or qualitative judgements. The analytical triangulation of qualitative and quantitative data can help one achieve in-depth understanding of results (Kang et al., 2019). After obtaining the Delphi results, the statistical validity of them is examined through a statistical test. Moreover, this study encouraged each of the researchers to separately analyze the results in two different places (respectively) located in two cities as well as to comparing and discussing them, establishing whether there are different results after analyzing the results from the Delphi survey and interview methods. This process can prevent researcher's bias, thus maximizing the accuracy and reliability of such analysis.

Research Process and Design of the Methodological Framework

The description of how to conduct the research process is shown in detail in Figure 1. The selection and use of three methods in the methodological framework — expert panels, the Delphi technique, and interviews (including e-mail interviews) — are designed so that they can complement or support each other.

Firstly, the literature on innovation types, technologies, and the industrial revolution was reviewed so that the relevant intellectual queries and gaps are understood. Secondly, the Delphi surveys and their questionnaires were designed, while the literature review was used to design the Delphi surveys, the interviews, and their questionnaires after three expert panel groups were composed in the triangulation of the recommender, who takes on the role of identifying and suggesting experts. Seven recommenders from 10 institutions were involved. Thirty experts were appointed and individually assigned three expert panel groups representing a group of (1) academic scholars and general experts, (2) public research and development institutes, and (3) private sector representatives (see Table 3). The expert panels were used for the Delphi survey and interviews. Thirdly, the Delphi survey was used to collect qualitative and quantitative information. Twenty-three responses were collected from among 30 experts during each Delphi survey. The first Delphi survey was performed to grasp the properties of innovation types and technologies for complementing and verifying the results from the analyses of Delphi surveys and interviews. By using the eight innovation types, the second Delphi sur-

Table 1. **The Existing Studies on the Classification of Innovation Types**

Direction	Literature
The identification of new innovation types as business model innovation and disruptive innovation, etc.	Christensen, 1997; Francis, Bessant, 2005, Miles, 2016; Pisano, 1996; Tidd, Bessant, 2018; Utterback, 1996
The demarcation between product and service innovations	Coombs, Miles, 2000; Hipp, Grupp, 2005; Miles, 2016
The distinction between product (or service) innovation and process (or service delivery) by focusing on manufacturing or service production	Davenport, 1993; Miles, 2016; Pisano, 1996; Sjodin et al., 2018; Utterback, 1996
The demarcation between technological and non-technological innovation, including managerial innovations	Birkinshaw et al., 2008; Damanpour et al., 1989; Erevelles et al., 2016; Francis, Bessant, 2005
The classification of innovation types based on the degree of technological change and product (or services) change	Abernathy, Utterback, 1978; Christensen, 1992a; 1992b; Henderson, Clark, 1990
The degree of technological continuity in terms of capabilities and market	Gatignon et al., 2002; Tushman, Anderson, 1986
The demarcation of business innovation and product (or service) innovation at different levels of a firm's activities	Afuah, 2014; Spieth et al., 2014; Tidd, Bessant, 2018
The rise of social innovations	Gault, 2018
The framework of four innovation types for a firm's capability development	Francis, Bessant, 2005

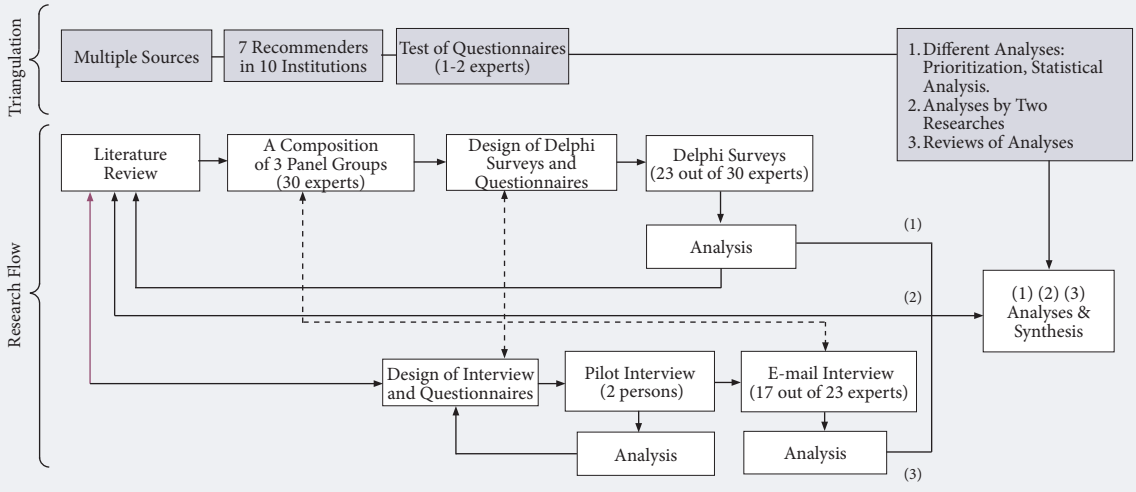
Source: authors.

vey was conducted with the three expert panel groups from August 18 to September 19, 2017. The questionnaires were designed in a relatively short-term period to assess the relative importance of each innovation type, through measurement on a nine-point scale for AI, big data, and IoT. Although performance improvements of each technology can be expected, through the interviews with experts, this study shows that the current development status of AI, big data, and IoT can be applicable at least over the five-year period. This period can fit with the purpose of this study. Therefore, it can help to foresee a firm's innovation behaviors with regard to each technology. Finally, on the initial analysis of the Delphi results, the semi-structured interviews were organized to confirm the results and to explore the reasons for the top-priority innovation types of each technology.

Two main questions formulated were with regard to (i) the agreement on top-priority innovations of each technology (three sub questions: AI, big data, and IoT) and (ii) the reasons for the top-priority innovation for each technology. The interview was constructed in two stages, comprising of (1) pre-interviews with two experts from October 2019, (2) e-mail interviews with experts were collected from November 18 to December 2, 2019. The e-mail interview was devised in combination with other interview techniques: face-to-face and telephone interviews regarding the resource constraints and physical limits. At the pre-interview stage: two interviews were conducted as telephone and face-to-face interviews, respectively. Two interviewers of different nationalities are the leading experts in the field of innovation and ICT.

Hence, the preliminary outcomes could be explored from the interview questions and what should be investigated was secured by obtaining information regarding innovation and the three technologies. The e-mail interview targeted 23 experts, who participated in the Delphi surveys. The e-mail interview can take the role

Figure 1. **Research Process and Flows**



Source: authors.

Table 2. **Category, Definition, and Sources of Eight-Innovation Types**

Technological Dimension	Types	Definition*	Selected Sources
Both	Business Model Innovation	A firm's innovation to introduce a new business model or modify an existing business model	Afuah, 2014; Andries, Debackere, 2013; Spieth et al., 2014
Technological Innovation	Product Innovation	A firm's innovation to develop a new product or improve an existing product	Francis, Bessant, 2005; Henderson, Clark, 1990; Yu et al., 2016
	Process Innovation	A firm's innovation to develop new or improved ways (or techniques) of producing goods or changing supply chains	Abernathy, Utterback, 1978; Davenport, 1993; Pisano, 1996
	Service Innovation	A firm's innovation to introduce a new service or improve an existing service	Coombs, Miles, 2000; Huang, Rust, 2018; Miles, 2016
	Service Process Innovation	A firm's innovation to introduce a new or improved ways of producing service	Andersson, Mattsson, 2015; Miles, 2006, 2016
Non-technological Innovation	Marketing Innovation	A firm's innovation to introduce new or improved marketing strategies or practices (or methods)	Birkinshaw et al., 2008; Erevelles et al., 2016; Moreira et al., 2012
	Organization Innovation	A firm's innovation to introduce new or improved organizations (or structures, forms)	Birkinshaw et al., 2008; Francis, Bessant, 2005; Lin, Lu, 2005
	Human Resource Management Innovation	A firm's innovation to introduce new or improved human resource managerial practices, processes, structures, and techniques	Birkinshaw et al., 2008; Laursen, Foss, 2003; Munteanu, 2015

Note: The definitions of the innovation types refer to the ones from OECD/Eurostat (2018) and the other sources.
Source: authors.

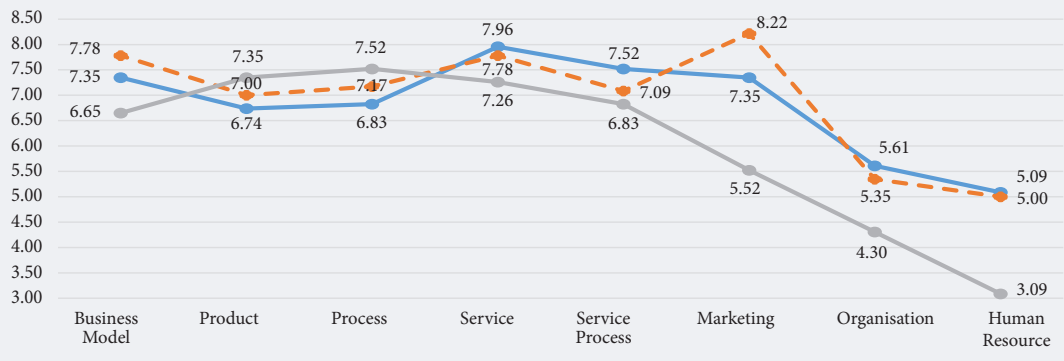
of complementing the results or exploring the reasons for the results. Seventeen responses were returned, but three of them contained no answers, along with some comments (see Table 3).

Data Analysis

In order to manage data from the expert assessments from the Delphi surveys and 19 interviews, each expert was allocated a unique identification (ID). By using their IDs, their data were anonymously and digitally sorted and managed. Their opinions and judgments were tabled to conduct the data analysis. In order to conduct the data analysis, the extensive studies of innovation types, technologies, and the fourth industrial revolution were reviewed as the means to obtain contextual knowledge for this study. At the first layer of analysis, the properties of innovation types along with AI, big data, and IoT were obtained. We attempted to identify the unique definition, characteristics, and intellectual geography of eight innovation types and each technology. This information can be used to complement the second-step analysis.

With regard to the top (different) priorities of innovation types for each technology, this study calculated the relative importance of each innovation type, which was collected from the Delphi survey, doing so by using the value of the mean through MS-Excel. After calculating the mean values of eight innovation types for each technology from the highest to lowest values, this study described the prioritized eight innovation types of AI, big data, and IoT, which are shown in Figure 2. To complement the results of differently prioritized inno-

Figure 2. **Relative Importance of Innovations Types amongst AI, Big Data, and IoT**



Source: authors.

Table 3. **A List of Experts' Affiliations and Participation in the Delphi Surveys and Interviews**

Affiliation	Delphi Survey	Interview
Academy and General Area (7)		
Catholic University of Korea	P	N
Han Yang University	P	(RP)
Institute for Information and Communication Technology Promotion	P	P
Korea Aerospace Industry Association	P	P
Korea Electronics Technology Institute	P	P
Korea Internet & Security Agency	P	P
Sungshin University	P	P
Industry (7)		
Deloitte Consulting Korea* (Inbyu.com)	P	P
EnerIdeas* (Seoul National University)	P	P
Hana Institute of Finance	P	P
Hyundai Research Institute	P	(RP)
Korea Small Business Institute* (Dashin Financial Group)	P	P
LG Economic Research Institute	P	N
Technovation	P	N
Public R&D Institute (9)		
Electronics and Telecommunication Research Institute	P	N
Korea Information Society Development Institute	P	P
Korea Institute of Energy Research	P	P
Korea Institute of Machinery & Materials	P	N
Korea Institute of Science and Technology Information	P	P
Korea Basic Science Institute	P	(RP)
Korea Research Institute of Bioscience & Biotechnology	P	P
Korea Research Institute of Chemical Technology	P	P
Science and Technology Policy Institute	P	N

Note 1: * Indicates the change of expert›s affiliation (New affiliation).
Note 2: P means Participation, (RP): Reply, N: No Response.
Source: authors.

vation types for the three technologies, a statistical test was conducted to confirm the differences between the eight innovation types of each technology and to check the differences among the three technologies and innovation types. Through the Delphi survey, this study obtained 184 cases respectively on the eight innovation for AI, big data, and IoT (Total: 552). The data are of the ordinal level. It is worthwhile to confirm the validity of this research through the statistical tests, although it is hardly applicable for inferential statistics, because expert selection can be a purposeful sampling, being considered non-probability sampling (Healey, 2002). The analysis of variance (ANOVA) was employed through means of the SPSS program and proved that the results are statistically meaningful. However, an important purpose of this study is to examine the different top priorities of the eight innovation types for each technology and therefore it ranked their mean values for each technology. This study identifies the top prioritized innovation types of each technology along with the other priorities.

In order to understand the reasons for the top-priority innovation types of each technology, this study conducted another analysis of the two pre-interviews with two experts and the e-mail interview data from the 17 experts responding to queries about (i) the agreement of top-priority innovations with regards to AI, big data, and IoT, and (ii) the reasons for each of the three top pairs. This study can identify whether or how many expert opinions are in agreement with the top-priority innovation types with respect to AI, big data, and IoT. By sorting the common content and comparing the different justifications for prioritizing innovations, this study can elucidate various reasons for experts' judgements on the three top pairs. Finally, different researchers individually analyzed the experts' opinions in different places and then compared their analyses in order to prevent an individual researcher's bias and increase the reliability of this study's analyses. In the next section, we present those results.

Top-Priority Innovation Types for and among the Three Technologies

Based on different values of innovation types regarding each of the three technologies, this demonstrates the different priorities of innovation types for them (see Figure 2). Twenty-three experts judged that service innovation is highly prioritized for AI (7.96). For big data, marketing innovation achieved the highest priority (8.22) among the eight innovation types. The analysis indicates that the highest innovation type for IoT is process innovation (7.52). After having the three top matches, twenty-three experts were given the statistical results of the three top matches for the interviews. Thirteen of the 17 experts agreed on the match between service innovation and AI. Thirteen out of the 17 experts consented to the match between big data and marketing innovation, which belongs to non-technological innovation. However, some disagreements of the match between IoT and process innovation were raised, compared to the other two matches. Three of the 17 experts said they partly disagreed on this match. One of them said it could be difficult to distinguish between which innovation types would be critical for IoT. Some experts argued that the emphasis on the process for IoT would reflect the business perspective rather than technological ones. As an engineer, one of the experts similarly found that the technological characteristics of IoT would not sufficiently explain what "process" innovation intends to achieve, while 10 out of the 17 experts agreed on the match between process innovation and IoT. Thus, there is a need to explore the reasons behind each match. They can be shown at the next section.

Table 4. **Differences in Eight Innovation Types on Each Technology: AI, Big Data, and IoT**

Section	BMI (sd)	PI (sd)	PPI (sd)	SI (sd)	SPI (sd)	MI (sd)	OI (sd)	HRMI (sd)	F (p-value)
AI	7.35 (2.145)	6.74 (1.514)	6.83 (1.337)	**7.96 (1.461)**	7.52 (1.504)	7.35 (1.668)	5.61 (1.644)	5.09 (1.649)	**8.420 (0.000)**
Big data	7.78 (0.998)	7.00 (1.348)	7.17 (1.193)	7.78 (0.998)	7.09 (1.411)	**8.22 (1.166)**	5.35 (1.774)	5.00 (2.000)	**15.754 (0.000)**
IoT	6.65 (1.873)	7.35 (1.555)	**7.52 (1.377)**	7.26 (1.738)	6.83 (1.800)	5.52 (1.928)	4.30 (1.964)	3.09 (1.756)	**19.532 (0.000)**

Note 1: Each innovation type's mean value is offered along with the value of standard deviation (SD).

Note 2: BMI (Business-model innovation), PI (Product Innovation), PPI (Process Innovation), SI (Service Innovation), SPI (Service Process Innovation), MI (Marketing Innovation), OI (Organization Innovation), HRMI (Human Resource Management Innovation).

Source: authors.

This study found that the results are statistically significant for (i) the difference among the three technologies in terms of the eight innovation types and (ii) the difference among the innovation types with respect to the three technologies. In order to understand the differences between the eight innovation types for each technology, this study conducted an analysis of variance (ANOVA). It obtained an F-value for the differences between the eight innovation types on AI, big data, and IoT. The outputs of ANOVA indicate that the eight innovation types of each technology are significantly different (See F-value of AI: 8.420; big data: 17.754; IoT: 19.532) (See Table 4). It implies that there would be different prioritizations among the eight innovation types of each technology.

By using the two-way ANOVA (factors: technologies, factor: innovation), it illustrates the differences between the three technologies: AI, big data, and IoT (F-value: 15.469). Otherwise, this study distinguishes between the eight innovation types (F-value: 37.299). Moreover, this statistical output shows the effects of interactions among the technologies and innovation types (F-value: 3.461). Accordingly, there are significant interaction effects. Thus, this study finds there are differences among the three technologies with respect to the eight innovation types and that there are differences among the innovation types with respect to the three technologies (see Table 5).

Reasons for the Top Three Pairs

In this section, we explore the reasons of why the three pairs were selected. The findings concern each pair.

AI and Service Innovation

The highest priority innovation type for AI goes to service innovation. Through the interviews, we discovered that the unique characteristics of AI are hyper-intelligence. An expert said AI already established the new technological paradigm through machine learning, such as deep learning and neural networks. In addition, the experts recognized that large amounts of data, as in big data, are required to effectively use AI. Although the ultimate technological development of AI will head for Artificial General Intelligence, a specialized AI has already reached the stage where the machine can play beyond the human being's intelligence through machine learning in some areas such as Go-game. An expert asserted that, as seen in the example of reinforcement learning having carrot-and-stick system functions, the technological property of AI may become similar by imitating the learning mechanism of a human being. Otherwise, one of the experts pointed out the convergence of AI with other technologies such as big data or robots, which leads to the convergence of the manufacturing and service areas. Thirteen experts stated that the real values from AI can be captured more in, or driven by, service innovation. They stated that the unique technological strength and advances of machine learning would be a strong reason firms are expected to be engaged in service innovation.

The unique dimension of service is to offer services with tangible products in the manufacturing or service industries. The technological capacity of AI is capable of offering customers more service-fitted products or enhanced service offerings. Some of the experts concluded

Table 5. **Differences of Three Technologies on Each Innovation Type**

Source	Sum of Squares	Degree of Freedom	Mean Square	F	p-value
Differences in the three technologies	79.609	2	39.804	15.469	0.000
Differences in the innovation types	671.819	7	95.974	37.299	0.000
Interaction	124.681	14	8.906	3.461	0.000
Error	1358.609	528	2.573		
Total	2234.717	551			

Source: authors.

that a product can be fitted with a function of service, then an AI-fitted product can be used for a non-human-involved service. One example is the auto truck fitted with a self-driving function. In the meantime, the voice-recognition-function installed speaker can be used in a part of the telecommunication service. The second dimension of service is the interaction with customers or employees in simultaneous production and consumption as opposed to tangible products or manufacturing production. Three experts showed some consent that AI can have a more capacity to intellectually respond to humans or others through machine learning. The intellectual ability of AI can modify the interaction process of service provision with customers (or suppliers) or employees, by offering more sophisticated interactions with or without any human intervention. Thirdly, one of the experts suggested that, because services have less or non-standardized (or heterogeneous) patterns compared to manufacturing, through machine learning AI can increase the functional capacity to recognize and predict the patterns of (more complex) human behaviors. It can increase service capacity and regulate various non-standardized services, leading to new service offerings. However, technological properties of AI show probability functions in a manner similar to those a human uses in solving a problem. This can help people to implement AI decision-making function in various service fields. As the 13 experts mentioned, firms could eventually perceive the advantages or benefits of service innovation with respect to AI.

Big Data and Marketing Innovation

Marketing innovation is selected as a highly prioritized innovation part of big data. The experts seemed to agree with the four Vs of big data: volume denotes the huge amount of data; velocity indicates the speed at which data are collected, accessed, and analyzed, ideally in real time; variety refers to the different structured and unstructured types of data; and the use of data increases socio-economic value (OECD, 2015). Contrary to the function of AI, an expert mentioned that big data technologically plays a role in exploring the hidden relationships between data, which have not been explored due to the shortage of collected data and the lack of computing capability to proceed and analyze the large volume of unstructured and structured data. It is able to help to identify the hidden patterns. However, two experts stated no big differences between big data techniques and the existing data processing techniques, such as a data mart or data warehouse, whilst most experts confirmed that big data can provide better technological performance. An expert said that the unique technological properties of big data are to achieve efficiency in speedily dealing with a huge amount of data and to expand the applicable range of big data, compared to existing data techniques. Thirteen experts mentioned that the benefits or values of the marketing innovation of big data, which firms are able to realize, are the reasons they are engaged in the marketing innovation of big data. The usage of big data can help firms to identify the hidden relationship between customers or market data by speedily proceeding the huge amount of data.

One of the experts emphasized that marketing innovation is the basis for big data usage. The adoption of big data can bring about a change in customer (or market) analytical practices in the technological capacity of big data, even though the origin of data analytics started in the field of marketing. The three experts mentioned that, through an analysis of customer or market big data, intelligence can lead to marketing innovations. Because the utilization of data correlates with the selection of a value or values to be explored, it can be asserted that big data has a strong influence upon the path of marketing innovation. One example is that, by analyzing the patterns and purposes of users' usage of social network services, it can create better contextual marketing strategies than what the social network service firms did before the use of big data. An expert said that big data is able to offer a firm some important market insights leading to marketing innovation. More importantly, some experts held the opinion that the use of big data in terms of customers or markets can create each firm's new activities, which can be connected especially to its business model innovation and product (or service) innovation. Most experts said that the technological capacity of big data and the need of customer preferences can lead marketing innovation.

IoT and Process Innovation

Process innovation is selected as the highest priority of innovation for IoT. This study noted that the unique characteristic of IoT can be abstracted into "hyper-connectivity" as a sensor network. A device attached to the node of each network can take on the role of transmitting data. The device can be a sensor or contain it. IoT is capable of expanding its coverage beyond the coverage of the devices traditionally connected to the Internet, such as laptops and smartphones, by including all kinds of objects and sensors that permeate public spaces, workplaces, and homes, monitoring other humans, animals, bodies of water, and other places, where people cannot reach. With (or without) human involvement, sensors can technologically work to gather data and to exchange data with one another. They need to have a good network capacity or speed, such as a fifth-generation network. Greatly enhanced network capacity is an indispensable factor in IoT. Some experts described IoT as another dimension of ubiquitous computing, such as the ability to compute anywhere, regardless of whether such a concept has been previously suggested or is now outdated. Despite of those arguments, most of all they highlighted the importance of sensor technology, because the current development of sensor technology is still in the embryonic stage. There are various emerging sensor technologies, including nano-robots, actuating technologies, etc.

The majority of the experts argued that IoT can be applied to each of the production processes in manufacturing, the operation of logistics (or supply chain), etc., so that it can help to collect information on each process or control the flows, quality, or speed of information or things during each process beyond the existing ones (although it can be applied to various areas). It can have a huge impact upon production, plant automation, logistics, and so on. It is able to cause the efficiency of process in various ways. One expert asserted that, if small-quantity batch production can be enhanced, the function of IoT can be frequently applied. As regards making a step forward, some experts stated that IoT can be considered as a technology of servitization by modifying or enhancing the processes for customers. Information from sensors or actuation can help each firm to automatically organize input orders for manufacturing and to schedule the delivery or replacement of products. This can be potentially enhanced into business model innovation and service innovation.

As a result, despite the negative opinions concerning this match, most experts concluded that IoT can create changes to the manufacturing, production, and supply chain areas, capturing process innovation. The technological characteristics and capacity of IoT, such as connectivity and sensing, can be suitable for process innovation. However, they stated that process innovation in IoT can direct firms to explore new business models, turning into a variety of business model innovations. Thus, the benefits of the process of innovation on the unique properties and characteristics of IoT are the reasons firms could be engaged in the process innovation of IoT.

Conclusion, Implications and Limitations

This study makes some important theoretical and practical contributions to innovation studies. First of all, by using the eight innovation types relevant to the new industrial revolution, this study identified different priorities for innovation with regard to each of the three main technologies. By forecasting the top-priority innovation types of each technology, service innovation for AI, marketing innovation for big data, and process innovation for IoT can were identified as the top-priority innovation types. The three top matches can imply dominant non- or technological innovation types in the new wave of the industrial revolution. The advantages of a specific innovation for each technology can be the reasons behind why a top priority innovation was selected. This study identified the theoretical implication of technology-push theory through the findings. In addition, the service innovation of AI and the process innovation of IoT can reflect the converging phenomena between the service and manufacturing areas. Through the marketing innovation of big data, this study implies that Damanpour et al.'s (1989) logic can be applied to other various managerial innovations. The three matches can be an indication of a starting point to prepare for the new industrial revolution.

This study has some limitations. The existing studies have identified different innovation patterns between manufacturing and service firms (Ettlie, Rosenthal, 2011; Hipp, Grupp, 2005; Lovelock, 1984; Miles, 2007; 2016; Santamaria et al., 2012). Although this study considers the important phenomenon of new conversion of the service and manufacturing industries, it was not able to identify different priorities and patterns for the eight innovation types between each service and manufacturing industry. Kang et al. (2019) examined the different priorities for technologies between the manufacturing and service industries. Their study implied different priorities of innovation types between the two industries. Therefore, it would be worthwhile to conduct a further study of innovation types between the two industries. Secondly, this study could not contain all types of innovation, including social and open innovation. Some studies noted a linkage pattern: product and process innovation, technological and organizational innovation, etc. This linkage pattern can be found in the combination of the three technologies. However, this study was not able to give a clear understanding of those linkages and did not put the main focus on the mixture of technologies. It would be useful to have a further study to look into the linkages between innovation types, including social and open innovation. The ethical, legal and social aspects (ELSA) of emerging technologies can be discussed within the framework of social innovation.

In practical implications, this study can give managers, engineers, and executive-level officers useful information of what innovation types they need to be concerned regarding AI, big data and IoT. In addition, it can provide some guidance to policymakers on what they should focus on with regard to top-priority innovation types for each technology in the decision-making process. Along with the three matches, specific characteristics of innovation types and technologies should also be considered. Secondly, this study can help firms when they construct their innovation portfolio in terms of their strategies and competencies. Top-priority innovation types for these three technologies can help managers devise their capability-building plan and manage the innovation process.

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Scenarios of Systemic Transitions in Energy and Economy

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Abstract

For the energy economics sector, earlier forecasting approaches (e.g., a Kaya identity or a double-logarithmic function) proved too simplistic. It is becoming necessary to systemically include the emergence of new discrete evolutionary changes. This paper provides a novel quantitative forecasting method which relies on the Global Change Data Base (GCDB). It allows for the generation and testing of hypotheses on future scenarios for energy, economy, and land use on a global and country level.

The GCDB method envisages systemic variables, especially quotients (such as energy intensity), shares (such as GDP shares, energy mix), and growth rates including their change rates. Thus, the non-linear features of evolutionary developments become quantitatively visible and can be corroborated by plots of large bundles of time-series data. For the energy industry, the forecasting of sectoral GDP, fuel shares, energy intensities, and their respective dynamic development can be undertaken using the GCDB method.

Keywords: energy foresight; global modelling; Global Change Data Base; scenarios; heuristic modelling; fuel mix; trends extrapolation; dynamics-as-usual scenario; land use change; saturation; autopoietic systems

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Introduction

Foresight methods and decision support systems are able to provide quantitative data material, analyze it suitably and derive conclusions for real-world economic decisions including energy (Lu et al., 2009; MacHaris et al., 2012; Mattiussi et al., 2014; Seuring, 2013). An earlier article in this journal (Ahamer, 2018) explained the functioning of the Global Change Data Base (GCDB) method, which maps trends from a system dynamics perspective. The GCDB detects country-wide dynamics of energy-related socioeconomic systems. Bundles of time series of per-country data can be plotted and visually analyzed by the GCDB analytical tool. From globally relevant public data, the GCDB provides re-computations, combinations, time derivatives, and their correlations with time, economic development (GDP/capita) and other structural variables in order to provide a consistent picture of global evolutionary trends (Castells, 1996; Christian, 2005). Such evolutionary trends can inform scenario-writing which further allows one to assess a country's room for maneuvering depending on various policy scenarios.

This article will apply the GCDB to energy and the economy and will detect "systemic transitions" — meaning the gradual restructuring within countries' institutions for energy economics and their rules of functioning along the evolution of the global systems of energy and economy. The GCDB and its analytical tool provides a more detailed scenario writing opportunities than current databases (e.g., the International Institute for Applied Systems Analysis, IIASA)[1] because it provides sector-specific and fuel-specific timelines for each country with much greater detail, as it includes several dozens of economic sectors and fuels.

Methods Used

The GCDB method consists of creating country-wide correlations not only of data points but of data series, and includes graphical representations which open themselves much better for interpretation than single mathematical numbers such as regression coefficients (r). GCDB's genesis and method was explained earlier (Ahamer, 2014, 2018, 2021) and the profits of combining often uncombined data sets such as FAO's land use data[2], IEA's energy data[3] and UNSTAT's economic data[4], after solving difficult compatibility questions regarding economic sectors and fuel types, which are defined differently in different data bases.

In practical work, the user selects the data sets to be correlated from a menu and displays them in either a logarithmic or linear manner on two axes of a coordinate system. The assumption of underlying "evolutionary trends" is more likely for such data correlations which show highly streamlined arrays of (averaged) lines than for those showing almost no correlation. For building theories, the most highly correlated plots are selected; and these are shown in the following chapters. Furthermore, building on such (graphical) trend extrapolations, options for policy making can be defined, especially in such cases where single states do not yet follow global trends or fall behind their structural potential. One example is the parameter of energy intensity which was lower by a factor of 5-10 in former communist countries (the former USSR, China) as compared to countries with free market economies. In this sense, the worldwide rising value of this parameter clearly correlates with human evolution proceeding from autocracies to democracies.

The factor formula using consecutive quotients

The GCDB allows for gaining more accuracy in the identification of long-term trends in the development of the global energy system based on detailed statistical analysis. For the above-mentioned target, an ordering structure for the parameters to be analyzed here is proposed as Figure 1, representing a well-known factor decomposition often referred to as the *Kaya identity* (Kaya, Keiichi, 1997; Peters et al., 2017; Feron, 2016), and including the key parameter population, economic activity (GDP), final energy demand (E_{final}), and primary (or raw) energy demand ($E_{prim.}$). All of these have to be analyzed as a time series on a per-country level.

The advantage of expressing recent historic development (and — in the case that reality can be projected at all — the near future) as a formula lies in the increased visibility of several distinct thematic areas within a logic chain, namely

- energy technology and fuels (described by the CO_2 emission factor CO_2 / E_p),
- energy conversion efficiency (described by the efficiency of converting primary to final energy, E_p / E_f),

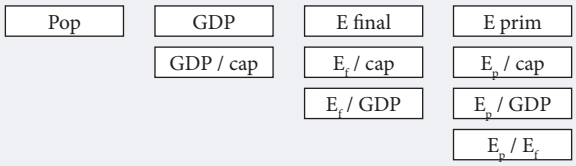
[1] E.g., the database supported by the International Institute for Applied Systems Analysis (IIASA). https://previous.iiasa.ac.at/web/home/research/researchPrograms/Energy/Databases.en.html, accessed 18.11.2021.

[2] The database supported by the Food and Agriculture Organization (FAO). https://www.fao.org/land-water/databases-and-software/ru/, accessed 18.11.2021.

[3] The database supported by the International Energy Agency (IEA). https://www.iea.org/data-and-statistics/data-browser, accessed 18.11.2021.

[4] The database supported by the United Nations Statistics Division (UNSTAT). https://unctadstat.unctad.org/EN/, accessed 18.11.2021.

Figure 1. **The Principal Set-up of the Statistical Analysis**



Note: Several sets of quotients of the key parameters are used such as population number, (final and primary) energy demand, and economic level (GDP).

Source: author.

- efficacity of an economy to provide output with a given amount of energy input, called "energy intensity" E_f / GNP),
- the economic level of a country described by per capita Gross Domestic Product GNP / capita) and
- the population.

This factor formula reads in the general notation as:

$$CO_2 = (CO_2 / E_p) \times (E_p / E_f) \times (E_f / GNP) \times (GNP / capita) \times population$$

where: CO_2 — level of CO_2 emissions; E_p — demand for primary energy (for a specific energy carrier); E_f — demand for final energy (for a specific energy carrier); GNP — gross national product (in a specific economic sector); P — population.

This same factor formula reads in the detailed notation, including sectors and fuels:

$$CO_2 (c, y) = \Sigma\, CO_2 (c, y, f, s) = [CO_2 (c, y, f, s) / E_p (c, y, f, s)] \times [E_p (c, y, f, s) / E_f (c, y, f, s)] \times [E_f (c, y, f, s) / GNP (c, y, s)] \times [GNP (c, y, s) / P (c, y)] \times P (c, y)$$

where: c = country, y = year, f = fuel, s = economic sector.

Unlike with simple correlations, the present theme of global evolution requires the careful handling of uncertainties and selective deviations from trends. Thus, the present article provides the most important of the above-mentioned quotients in a graphical manner in order to portray the levels, increase rates, trends, and statistical deviations of the presumed trends in an easily perceivable manner. Therefore, this article deems it more suitable to provide a graphical means of presentation as compared to a presentation of mere numbers representing the correlation factors.

Data and projections used

The present article uses past data only, and depending on their specific interest or the apparent correlation coefficient, the reader may extrapolate data into the long-term future, which will require personal paradigms on how world history is likely to function (Christian, 2018). Evidently, extrapolation by a few years might seem safer than by a few decades. In the following figures, for most cases this projection is not undertaken explicitly by using single lines because such line-drawing could create the false impression of safe assumptions regarding future trends. Therefore, the author refrains from explicitly "computing the future" by a regression formula. Actually, reality is far more complex than can be described by a handful of statistical parameters and includes innovation, saturation stages, political conflicts, and culturally produced deviations from seemingly stable trends (Ahamer, Kumpfmüller, 2013), among which recent decisive climate change policies which already visibly curb some countries' CO_2 emissions. Therefore, the continuation of trends represents rather mere hypotheses for structural change in many cases, which then still have to be counterchecked against their real-world likelihood.

Which Systemic Transitions Have already Taken Place in the Past?

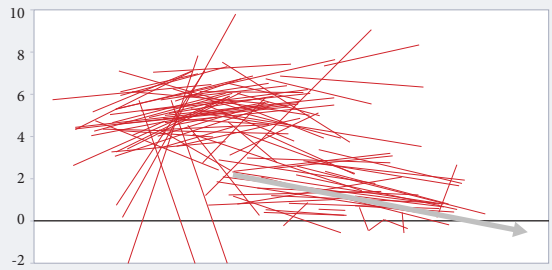
Additionally, to the mainly evolutionary character of historic development, distinct steps or leaps can be perceived in the structural-functional interplay between the techno-socio-economic parameters of the anthroposphere; thus leading to a stepwise, ever more complex self-creation of the noosphere (Jäger, Springler, 2012; Kondratieff, 1984; Christian, 2018; Raskin, 2016). During this co-creative evolution to a humanized world, "yet varieties of global disruption (barbarization) and progressive transformation (great transition) remain plausible alternatives"— as we especially witness currently.

On a more general level, we perceive a steady shift between those domains which exhibit virulent growth during some historic epochs while showing stagnation beforehand and afterwards (such as population, Gross Domestic Product GDP, final energy E_f, and primary energy E_p). In world history, there are transitions (Christian, 2005) visible which represent rather rapid systemic structural changes, including

- the population transition,
- the deforestation transition or land-use transition,
- the transition among several energy sources which have their corresponding main pollutants.

This stepwise "*evolution in transitions*" makes mere trend projection irrelevant as a scientific method and practically-minded foresight toolbox, but instead suggests a more inspired retrieval of crucial points determining the overall civilizational dynam-

Figure 2. **Population Growth Rates in All Countries of the World during the Last Few Decades**



Note: A possible path for industrialized countries such as Russia or Austria is shown in grey.
Source: author.

ics such as saturation points, turning points, and the seemingly unexpected creation of new phenomena. The GCDB method takes such complex dynamics into account by analyzing the 1st and 2nd time derivatives of data series (Ahamer, 2018).

Population explosion and population transition

One of the best-known structural transitions of the anthroposphere is the so-called *population transition* or demographic transition (Galor, 2012; Akaev et al., 2012). This first type of evolutionary transition is well documented and well explained in scientific literature based on several decades-long analyses (Chen, 2014; Fischer, 2008; Zhang, 2002; Du, Yang, 2014; Toft, 2007; Shen, Spence, 1996; Ssewamala, 2015; Jeníček, 2010; Nielsen, Fang, 2007) and therefore serves as the first example for how the GCDB illustrates global trends. As a function of increasing education, birth rates in many countries decrease (Kravdal, Rindfuss, 2008; Mills et al., 2011; Raymo et al., 2015; Upadhyay et al., 2014) while depending on several framework conditions; and as a function of increased medical support, death rates decrease in similar time periods.

The relevant aggregate change rate is population change (d pop/dt) which has already slowed down, as Figure 2 shows for the growth rates as a function of GDP/cap (each red line meaning the time average of a country during 1960–1991). Thus, our earlier global problem of a population explosion has already turned into our present problem of "population shrinkage", especially in countries of the "Global North".

Figure 3. **Deforestation (in percent of arable land area) as a Function of GDP/Capita**

Note: From left to right, along evolution, chronic deforestation even turns into afforestation in developed countries.
Data sources: FAO, World Bank, GCDB.

Deforestation in order to gain new arable land

The second type of transition is mentioned in literature and commonly named "land use transition" (Lambin, Meyfroidt, 2011, 2019; Hurtt et al., 2006, 2011; Macedo et al., 2012; Baumann et al., 2011; Grau, Aide, 2008; Rounsevell et al., 2012; Long, 2014; Long et al., 2014; Munteanu et al., 2014; Powers et al., 2011; Long, Qu, 2018; Meyfroidt et al., 2018; Nuissl et al., 2009)[5] including various shades of this global trend. To evaluate this massive trend, the GCDB provides long-term trends for country-wide averaged values.

The setting aside of agricultural areas has replaced the former pressing need for "*new agricultural land*", which earlier caused deforestation. This is becoming strikingly visible in Europe and countries with high GDP/capita and is displayed in Figure 3 as a function of GDP/capita.

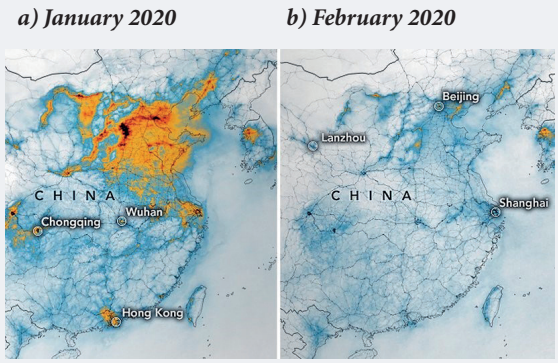
The key message of this figure is that apparently with growing development, less deforestation is needed to maintain an economy. The more a country develops, the less deforestation activities become necessary and even reafforestation can be undertaken. At the same time, the limits are illustrated of a concept that attempts to portray the economic future as a mere function of the economic past. The principal necessity for a multi-paradigmatic methodology of foresight (Vester, von Hesler, 1980; Ahamer, Jekel, 2010) is already felt here.

Epochal systemic changes in air pollution and the energy fuel mix

During recent environmental protection history, we can even observe a systemic and epochal change in the air pollutants considered the most relevant and these correlate with the evolutionary changes of en-

[5] Alternative term proposal is "deforestation transition" as chosen by the author (Fagua et al., 2019).

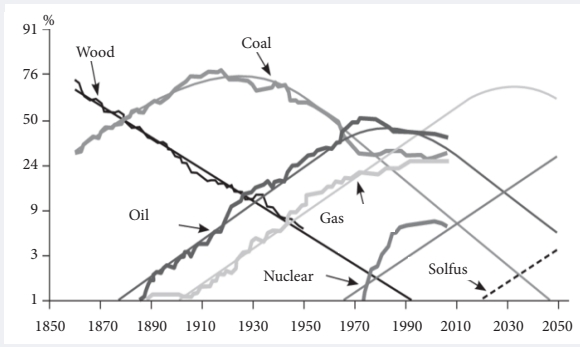
Figure 4. **The Concentration of Nitrogen Oxide in the Air above China**



Note: One can see strong decreases in concentration of nitrogen oxide as a result of the Corona virus pandemic and related economic limitations.

Source: https://www.zeit.de/2020/14/emissionen-corona-krise-klimaschutz-treibhausgase-co2, accessed 19.01.2022.

Figure 5. **The "Marchetti Curve"**



Note: The "Marchetti curve" had hoped to explain past and project future energy carrier percentages according to a logistic substitution model. As we see, earlier prognoses for growing nuclear shares did not come true (Ahamer, 2012), and the "solfus" (= solar or fusion, then still undecided) turned out to be renewable energy, not fusion energy. Seen from now, this curve is a historic document from a techno-optimistic era.

Source: adapted basing on (Marchetti, Nakićenović, 1979).

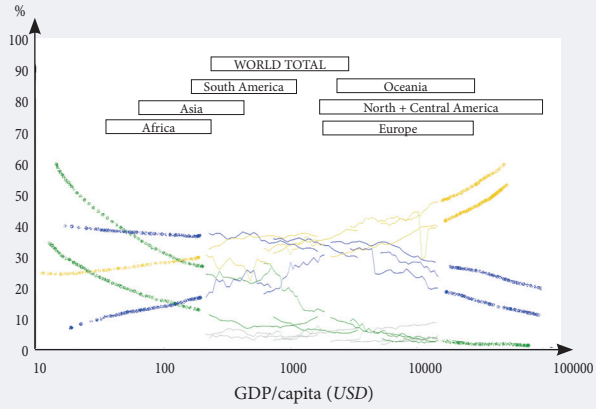
ergy sources "on the catwalk", i.e., in the perception of environmentally interested persons. First in the early days of environmental protection: these were dust, CO, and SO_2 which represent "classical pollutants". Later NO_x and hydrocarbons (often from traffic sources, see Figure 4) become relevant for ozone formation and causing respiratory diseases. Afterwards CO_2 and greenhouse gases (GHG) came to attention as systemic effects of any fossil-based society (Meadows et al., 1972; Lovelock, 1988).

Therefore, we can conclude: every time period has its mode of environmental pollution, ranging from small-scale coal dust and CO pollution to the globally relevant greenhouse gas CO_2, and this changes according to humanity's environmental understandings. Experience shows that these environmental problems were (at least partially) solved in this historic sequence: during the 1960s until the 1990s, dust, CO, and SO_2 were lowered considerably, mostly by (end-of-pipe) filter technologies, during the 1990s-2010s ozone precursors were reduced, and presently GHG are the focus of environmental action worldwide. In the same sense, there appears to be a trend from individual to systemic, namely from an individual case of a limited problem (e.g., from an individual, easily identifiable industrial chimney) to a pervasive *systemic* and structural problem with myriads of emitters (such as households and traffic) that includes a strong behavioral component. The crisis of COVID-19 coronavirus offers an unexpected insight that air emissions can actually be reduced from one month to another to such a considerable extent that it even suffices as a climate protection measure (Figure 4).

As a second example, the historic sequence of emphasis on changing market shares of energy sources seems to follow a regular pattern at first sight. This led early researchers to assume a double logarithmic curve as was propagated by Italian Cesare Marchetti who plotted relative market shares (f) against time (Marchetti, Nakićenović, 1979). The following image (Figure 5) emerges in his vision: after an early historic biomass era, there follows the coal era, then the oil era, currently the gas era and — in these authors' vision of the future — the nuclear era, which was even more desired at that time. These analysts remain partly undecided regarding the future: as an interpretation of the ambiguous abbreviation "solfus", every reader can make their own interpretation of what this abbreviation means: solar or fusion, depending on the preferences of any given reader. This example shows that in former decades, research tried to remain entirely value-free, according to the paradigm of "pure science" during these times. The so-called *Marchetti curve* represents successive epochs with different predominant energy sources according to their market shares f, which are plotted into a double-logarithmic horizontal scale (f/(1–f)), see Figure 5. This curve became well known, but still did not prove sufficiently correct, based on how the situation actually developed with the benefit of hindsight (i.e., 40 years later in this case) which proved the earlier presentation of this information to be partly incorrect.

In the author's view, this example underlines the fact that relying too much on an ideological paradigm might mislead forecasting activities and distort suggested scenarios.

Figure 6. **The Three Main Economic Sectors Plotted for Each Continent as a Function of GDP/Capita**



Note: Agriculture marked as green; industry — blue; services — yellow. In order to highlight possible "paths of development", sprayed colours suggest lines outside the actual scope of data.

Source: author, using data from (Ahamer, 2019) and GCDB.

Which Economic Sectors are Important during Evolution, and to What Extent?

This chapter presents the diagnosis of evolutionary shifts among sectors of an economy as a function of economic development and provides various graphic representations for this evolutionary analysis.

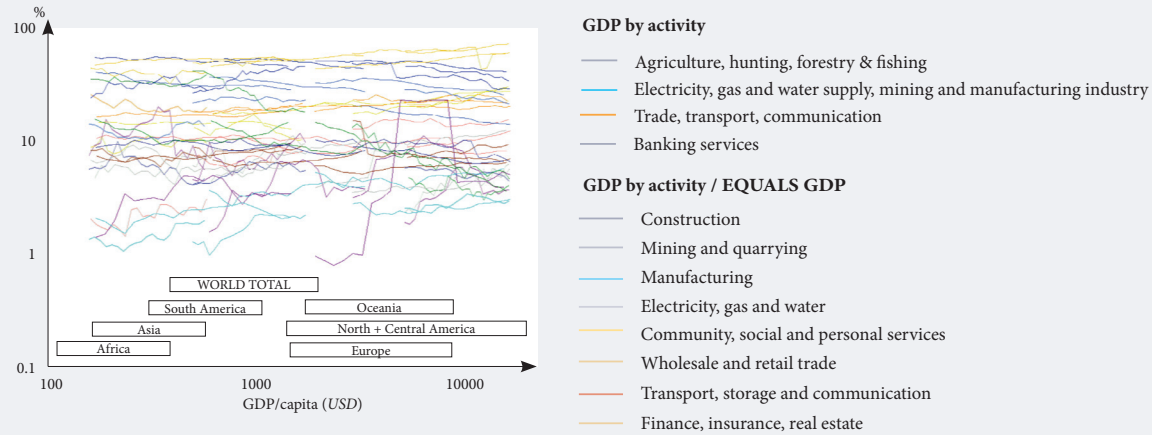
Graphically representing development paths for sectoral GDP by continents

One key interest of any forecasting activity is finding structural shifts within global economic systems (Sterman, 2000; Abler et al., 1971; Duraković et al., 2012). This means, to what extent do the sectors shift, and in which sequence? Expressed in other words, what is important to the population, by which economic activity is their attribution of importance expressed and by how much economic effort is their drive to express their preferences implemented in reality? What is essential for an economy is expressed to a large extent by the percentage share of the relevant economic sector; for example, the expenses and services that are made by these sectors. Existing gross national product data allow such a representation in a uniform manner through the value for all countries in past decades.

As a first step, continent-wide representations of the percentages of the three main GDP sectors as functions of these continents' economic levels (GDP/cap) are arranged in Figure 6, where each continent is shown by graphs allocated to this continent's GDP/cap levels. Sprayed lines in the three colors suggest a window width in which so-called "paths of developments" could continue on our planet, including a supposed history covering smaller GDP/capita levels. However, it should be kept in mind that assuming the existence of "paths of development" at all represents an act of implicitly subscribing to one of several possible opinions within the realm of developmental paradigms: the notion of development paths means identical pathways for any evolution, and that all countries would more or less follow the track of "the most developed" nations. Such developmental optimism (provided by internal growth theories), however is contrasted by dependence theories (Fischer et al., 2016; Ahamer, Kumpfmüller, 2013; Bader et al., 2013, 2014).

As a second step, continent-wide representations of the percentages of the ten GDP parts as functions of these continents' economic levels (GDP/cap) are shown in Figure 7, which provides more details but at the same time less easily traceable "paths of development", and more disturbance by potential changes in data coverage producing stepwise functions.

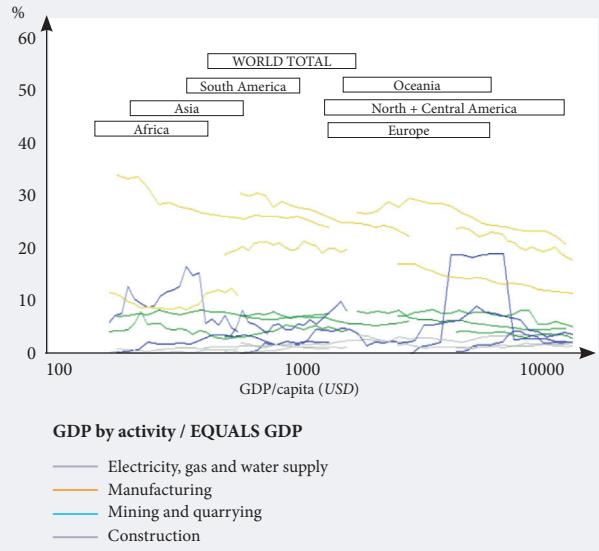
Figure 7. **The Ten Economic Sectors Plotted for Each Continent as a Function of GDP/Capita on a Logarithmic Vertical Scale**



Note: Agriculture marked as green; industry — blue; services — yellow.

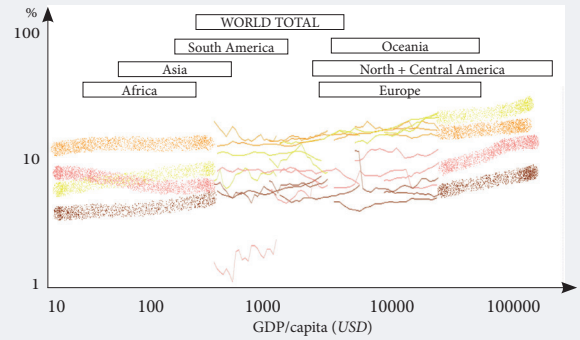
Source: author, using data from World Bank and GCDB.

Figure 8. The Four Industrial Economic Sectors Plotted for Each Continent as a Function of GDP/Capita on a Linear Vertical Scale



Source: author, using data from World Bank and GCDB.

Figure 9. The Four Service Economic Sectors Plotted for Each Continent as a Function of GDP/Capita on a Logarithmic Vertical Scale



Source: author, using data from World Bank and GCDB.

As a next step, Figure 8 explores the details of industrial sectors only while using a linear scale — in contrast to the logarithmic scale of Figure 7. It becomes clear that the dynamics of small values of a few percent only become more visible on a vertical logarithmic scale, which better complies with an implicit paradigm of "presumably constant relative change rates during development" (Estep, 2002), which thus will be kept in use in the future.

Better visibility of alleged "paths of development" can be achieved by logarithmic (as opposed to linear) plots, which is corroborated by Figure 9 showing the generally rising percentage shares of service sectors on any continent. The GCDB generally relies on graphic *pattern recognition* and tends to understand better pattern discernability as better explainability for an evolutive formula. Thus, any evolution tends to obey exponential building laws as opposed to linear building laws.

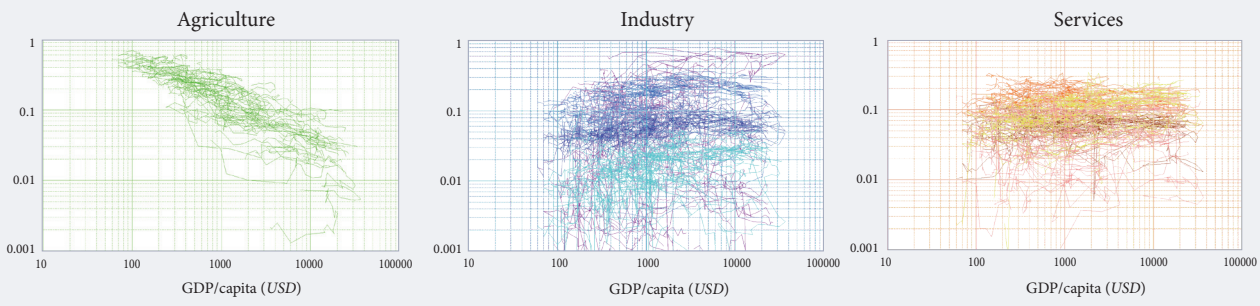
The methodological message of Figure 10 is that a plot of all single countries without using a time-average representation could likely provide a less clear picture as compared to using spatial or temporal aggregates, which is done in other figures.

The above-mentioned type of economic transition between sectors has been known for a long time (Haggett, 2001), and the GCDB allows one to quantify its relative speed and periods of onset for all single sectors. By doing so, "economic transition" becomes a generalizable "natural law" for all countries.

Visualization of development paths for sectoral GDP by countries

This subsection shows how various manners of graphical representation (of one and the same data) allows for the recognition of various sub-aspects within the economic transition as a global phenomenon.

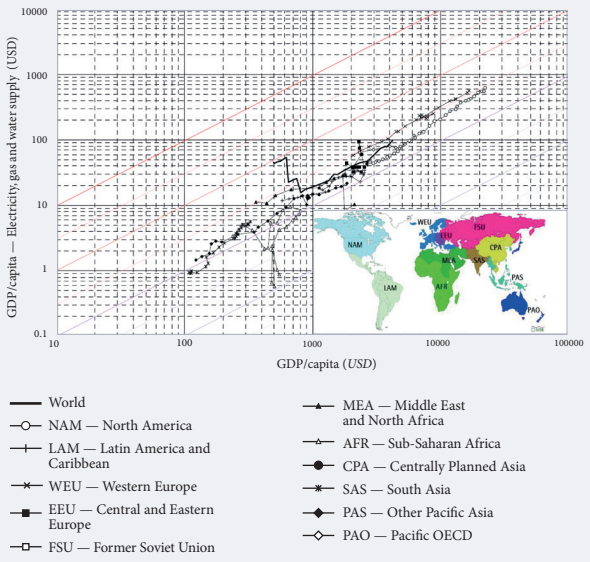
Figure 10. The Three Main Economic Sectors as Composed by their Respective Single Sectors



Note: Vertical axis reflects the ratio "GDP per capita / EQUALS GDP". Data plotted for each continent as a function of GDP/capita for each single country. Agriculture marked as green; industry — blue; services — yellow.

Source: author, using data from World Bank and GCDB.

Figure 11. **Development of the Sectoral GDP/Capita of the Electricity Generating Industry as a Function of GDP/Capita**



Legend for diagonal lines: red = 100% share of total GDP, pink = 10% share, violet = 1%, grey = 0.1%.

Note: Incomplete data supply by single countries may cause jumps in data curves. The eleven world regions equate IIASA modelling, as described by the map insert.

Source: author, using data from World Bank and GCDB.

Based on the above experiences with graphical representations depicting the *intra-sectoral shift* occurring during economic evolution (in possibly systematic manner, which is still to be analyzed), a new method of presenting is being developed now.

On the one hand, all evolutionary information is best plotted as a function of GDP/capita; on the other hand, the percentage rates of every single economic sector should be clearly visible. Additionally, appropriate (spatial and temporal) averaging is recommended in order to render the development paths visible.

As a first example of a type of presentation as well as of the variability between geographical regions, Figure 11 plots the development of GDP per capita for the energy-related sub-sector named "electricity, gas, steam"[6] as a function of GDP/cap. The definition of eleven regions complies with IIASA models (IPCC, 2002; Ahamer, 2008, 2014, 2015).

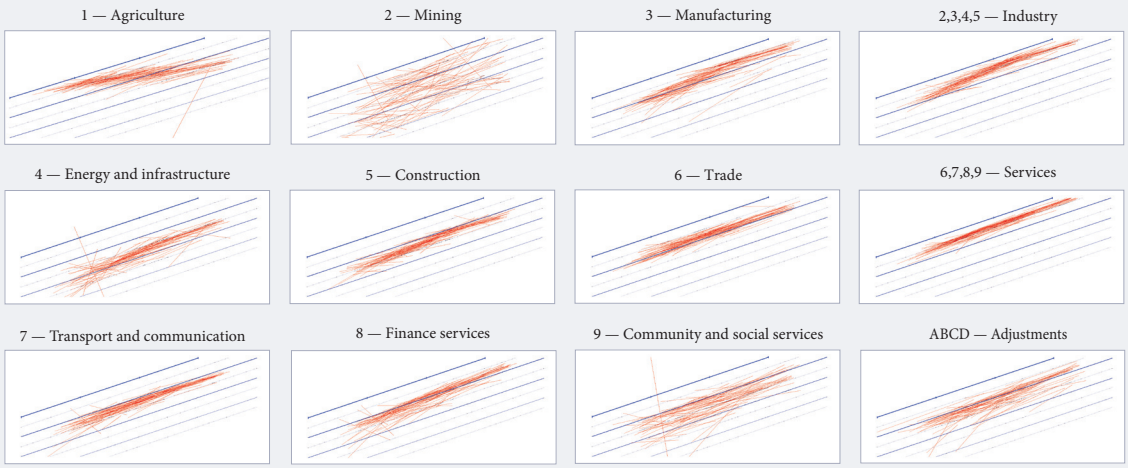
In the course of overall economic growth, the GDP of this single sub-sector also increases; and therefore, the curves of all continents point towards the top right. The percentage of total GDP can be read by comparison with the diagonals, which are therefore explicitly marked. Greater inclination upwards in Figure 11 means a positive rate of increase in Figure 13.

Figure 12 shows the same information as Figure 11 for the entirety of all nine economic sectors, plus for the aggregates industry, services, and statistical adjustments. The sequence of diagonal lines is the same as in Figure 11, only in blue color.

It becomes visible that a few sectors do not seem to follow a "development path" but rather obey local geographical circumstances; the most visible sector being mining – which becomes clear when understanding geographic and geologic criteria for mining activities which do not depend on a country's economic level. Other sectors' development seems to exhibit a rather clear "evolutionary path".

In a next step, the change rates of the percentages of all nine sectors are displayed in an explicit manner.

Figure 12. **Development of the GDP/Capita of All Nine Economic Sectors as Function of GDP/Capita**

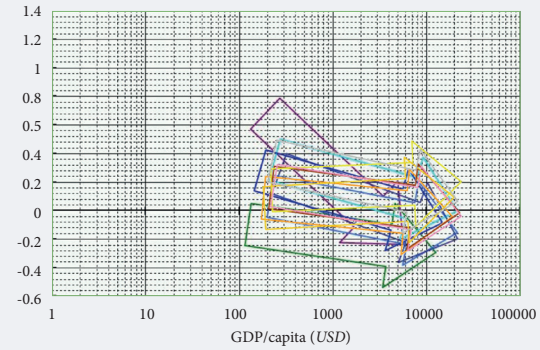


Note: Legend for the sequence of diagonal lines as in Figure 10

Source: author, using data from World Bank and GCDB.

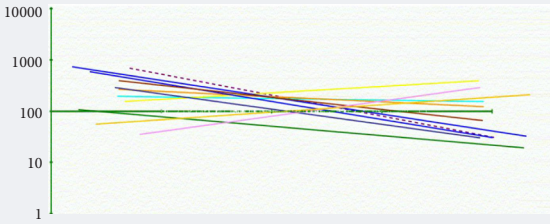
[6] According to UN economic categories. See: https://unstats.un.org/unsd/trade/classifications/SeriesM_53_Rev.5_17-01722-E-Classification-by-Broad-Economic-Categories_PRINT.pdf, accessed 14.01.2022.

Figure 13. **Arrows for the Change Rates for All Nine Sectorial Percentages as a Function of GDP/Capita**



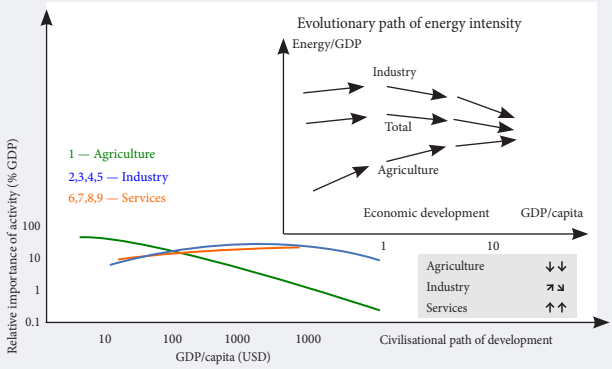
Note: Legend for the sector colours see in Figure 11.
Source: author, using data from World Bank and GCDB.

Figure 14. **Change Rates (in %) for All Nine Sectors as a Function of GDP/Capita**



Note: Legend for the colours of the sectors as in Figure 11.
Source: author, using data from World Bank and GCDB.

Figure 15. **The Resulting Presumed Development Path for the Three Main Economic Sectors Plotted Globally as a Function of GDP/Capita**



Note: Agriculture marked as green; industry — blue; services — yellow. The insert provides yet more detail by suggesting a path for the related energy intensity in agriculture and industry.
Source: author, using data from GCDB.

Figure 13 shows arrows which equal roughly the trends for change rates when averaging across all countries worldwide. In another type of depiction, Figure 14 provides the averaged change rates for all nine economic sectors, again measured as percentage points.

Conclusions for the shift in sectoral GDP

Based on analysis of the previous figures and by selecting those economic sectors with growing increase rates, the following conclusions can be made regarding sectors promising further expansion of their economic activities in the medium and long term (i.e., showing positive rates of increase in the right part of Figure 14):

- Technological infrastructure, i.e., electricity, gas, water: currently has a low level, but very high growth rates,
- Transport and communication,
- Financial services and insurance,
- Community and social services.

It is essential in this analysis that rates of increase themselves are viewed as variables. Passing the zero line in Figure 14, hence changing the sign mathematically, marks a transition process similar to the well-known population transition.

The grand picture is delivered by Figure 15 showing the hypothesized path for agriculture, industry, and services as a function of the economic level. As an interpretation, economic levels (sectoral GDP/cap) translate to the "perceived importance" of the related societal activity.

Which Overall Trends Exist in the Energy Sector?

Let us go to the analysis of the energy transition, which explicitly offers huge opportunities for Russia (IRENA, 2017a, b; IRENA, 2022; Grechukhina, 2021). Conventional projections of energy demand mostly conceive the demand for energy as linear or growing slightly exponentially (IPCC, 2002; IIASA, 1998). Often, this is on the basis of earlier research at IIASA assuming a worldwide and uniform *constant* numerical value for the improvement of energy intensity (E/GDP), namely –0.8%. Are there better ways to map global dynamics?

Rate of increase for final energy

First of all, this article presents the rates of change for energy demand over time (Figure 16). In this and the following figures, only the red average line is shown but not the strongly oscillating actual

values. It is striking that the rates of increase converge to about 1% in the right-hand side of the figure, which means the economically more developed countries — and secondly, those rates start to sink; in some cases, they already seem to have become negative. If one continues the development mentally, the negative growth of the energy requirements means an expected reduction of energy demand in the developed nations.

This self-organizing dynamic behavior ultimately might regulate the entire global energy problem and the greenhouse effect problem. *This is the energy transition*. It is obviously caused by negative feedback cycles in the global energy system.

Per capita final energy demand and its rate of increase

In this subsection we perceive that across all political systems and economic levels, the growth of per-capita energy consumption levels off and thus represents one of the most stable and most characteristic trends of the worldwide "energy transition". For the individual countries, according to Figure 17, the per capita final energy demand is initially positively correlated with GDP/capita. This is in line with the widely known fact that economically developed countries have higher per capita consumption; and additionally, such consumption increases over time. Both facts together lead to very pessimistic assessments about the increase in energy demand being unavoidable.

We also see that historically dramatic "learning effects" are possible, namely that economies with previously lower GDP/capita (e.g., China) may already hit the path toward decreasing E/cap. Figure 18 provides the data for the rates of change for E/cap, (which further adds to the clarity that E/cap growth actually saturates).

Energy intensity (E final / GDP) and its rate of increase

In general, viewing the quotient energy intensity (= final energy / GDP) characterizes entire economies. As a fundamental strategy against global warming, decoupling energy demand from economic growth has great potential — but must be filled with practical measures on a concrete pragmatic level. Viewing Figure 19 may even lead one to consider the decrease of energy intensity natural law.

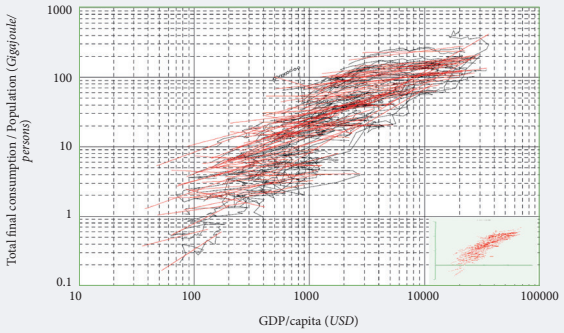
A finer picture of the (possibly inherent) dynamics of reducing E/GDP is perceivable from Figure 20: in a medium phase (around a GDP/cap of 1000–2000$/cap), economies show almost no improvement in energy intensity, while afterwards strong gains in energy intensity become possible (at bottom in Figure 20).

When identifying components within the global "energy transition", the partial effect of ever more ef-

Figure 16. Development of the Rate of Increase in Final Energy Consumption in Petajoules PJ (E final) as a Function of GDP/Capita

Note: This rate obviously decreases in the course of evolution.
Source: author, using data from IEA and GCDB.

Figure 17. Illustration of the Final Energy Consumption per Capita as a Function of GDP per Capita



Note: In the insert only the red trend lines are made visible. This variable seems to approach a state of saturation.
Source: author, using data from IEA and GCDB.

Figure 18. Rate of Change in Final Energy Consumption per Capita as a Function of GDP per Capita

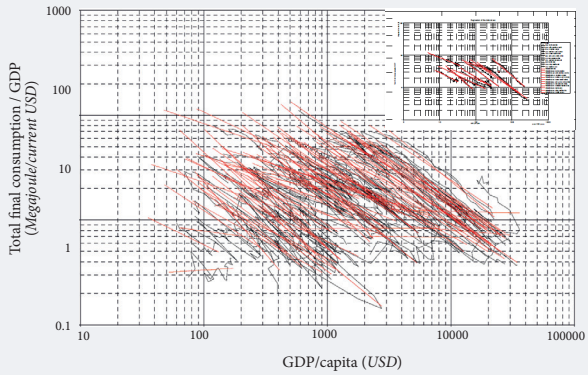
a) for all individual countries

b) aggregated for the continents

c) for the eleven regions

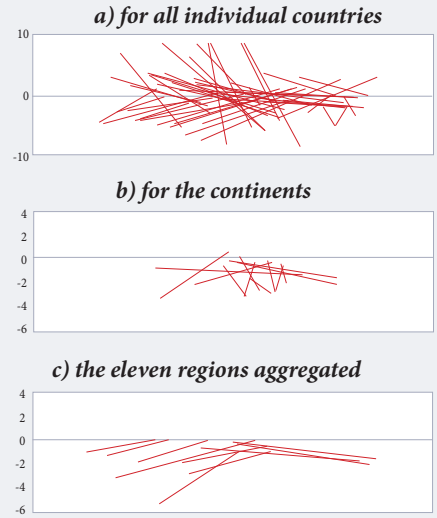
Source: author, using data from GCDB.

Figure 19. **Energy Intensity for Producing a Unit of Value Added (Energy Consumption per Capita) as a Function of GDP per Capita**



Note: In the insert only the eleven regions are shown.
Source: author, using data from IEA and GCDB.

Figure 20. **Rate of Change in Energy Intensity as a Function of GDP per Capita**



Source: author, using data from GCDB.

ficient provision of economic output per energy input is revealed as a key contributing factor by means of the GCDB's quantitative data.

Which sectoral trends exist in energy demand?

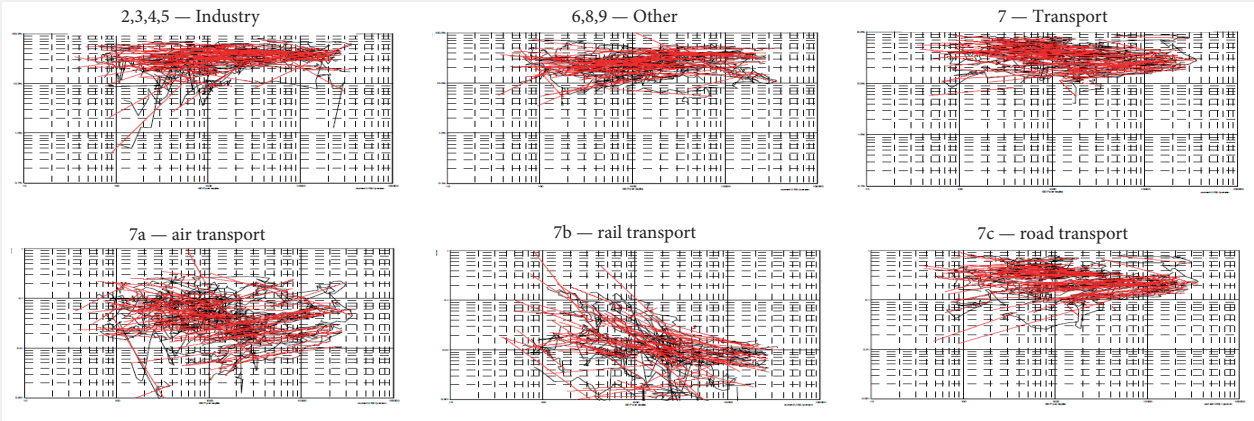
Percentage of final energy consumption in some main sectors

The approximately 30 economic sectors of the IEA database[7] are unfortunately different from those in UN economic statistics and therefore the (principally seemingly easy) quotients from Figure 1 cannot be computed in all cases, especially when sectoral data for both energy and GDP data are required.

In order to provide a reasonable and feasible illustration, Figure 21 shows some telling examples of the percentage of final energy consumption, including in industry, service, and transport, while using the earlier colors of the headings.

The evolutionary and developmental processes described in the previous chapters are widely known and statistically clearly corroborated. In contrast to the GDP-related breakdowns in the earlier chapters,

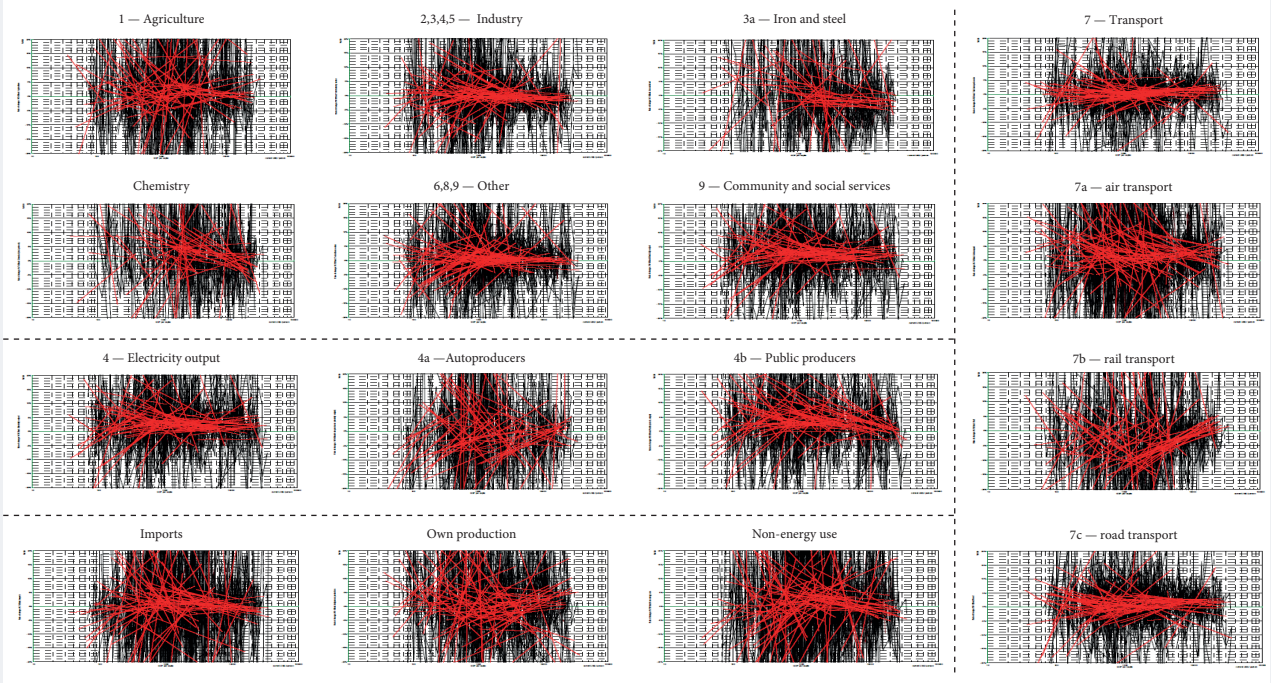
Figure 21. **Share of Energy Use in Three Main Sectors**



Note: Roughly the same size of energy use (above), and, as a detail, the breakdown within the transport sector (below), using red trend lines for all countries.
Source: author, using data from GCDB.

[7] Its position within the GCDB is integrated within Figure 17 in (Ahamer, 2018).

Figure 22. **Growth Rates in the Shares of Energy Use in Individual Sectors**



Note: Includes details of the breakdown within the electricity sector (centre) and its supply modes (bottom). Again here, a red trend line is shown for each country, and the zero percent line is situated in the image centre.

Source: author, using data from GCDB.

this chapter provides shares of energy consumption (as part of total energy demand), according to various domains of usage of this energy, as depicted in Figure 21. As one example, the *transport* sector (brown) comprises a strikingly large percentage of energy consumption. In addition to the classical service sector, the "*other*" sector (yellow) also includes households, which are not associated with the generation of sectoral GDP. Detailed quotients (E_i/GDP_i) are therefore not always clearly possible.

Rates of change of percentages of energy use by sector

This section shows change rates of variables shown in the previous section. The country-by-country representation of the sectoral growth rates (Figure 22) enables the better perception of dynamics, especially for developed countries at the right in the images. According to visible trend lines and correlations, data are interpreted as follows:

- The constant increase in the energy demand share for road traffic is likely to continue in the short and long term.
- The previous growth rates for the share of energy demand in aviation remain high, but in the medium-term in economically very developed countries this may increase even further, in the moderately-developed countries, it should slow down.
- The relative decline in energy consumption share for the railways remains constant for the time being, but in the medium term can turn into a noticeable increase in highly developed countries.

Other observations are summarized at Table 1.

Percentage of final energy differentiated by energy sources

This chapter deals with the development of the percentages of each (one of over twenty) energy sources. The graphical representation of the energy carrier shares uses a more concise form of representation (namely by region, not by country as before) (Figure 23) and this is done again in the medium and long term.

The following energy sources are declining: coal and heavy oil in the medium term, all oil products (after their expiring short-term increase) such as diesel and gasoline in the long term. In the medium term, growth is expected for natural gas, electricity, while in the long-term this growth is expected for biomass, heat, and jet fuel.

Table 1. **Interpretation of Some Trends Identified within Figure 21**

Perspective	Trends
Short-term (5-10 years)	• The (low) share of energy consumption in agriculture tends to increase • The (already high) energy share of industry is falling, particularly strongly in the iron and steel sector • The electricity generated as a share of total energy consumption continues to rise significantly, mainly generated by public electricity producers • The domestic production of energy sources is increasing. • The share of energy consumption for the service sectors is continuously increasing slightly
Medium-term (10-20 years)	• In the long term, the proportion of electricity generated at companies themselves ("own production") begins to increase • The proportion of non-energy use that has risen to date begins to fall in the long term • Imports, which have risen so far, are beginning to decline again • The previously high rate of increase in the share of energy consumption for the chemical industry begins to decline in the long term • The previously high rate of increase in the share of energy consumption for the transport sector remains high and is growing

Source: author.

Rates of change in percentages of final energy differentiated by energy sources

More striking information and thus more insight into global dynamics is provided by plots of the increase rate of energy carrier shares. These are displayed in Figure 24.

This diagnosis results in statements about possible long-term shifts in the energy mix:

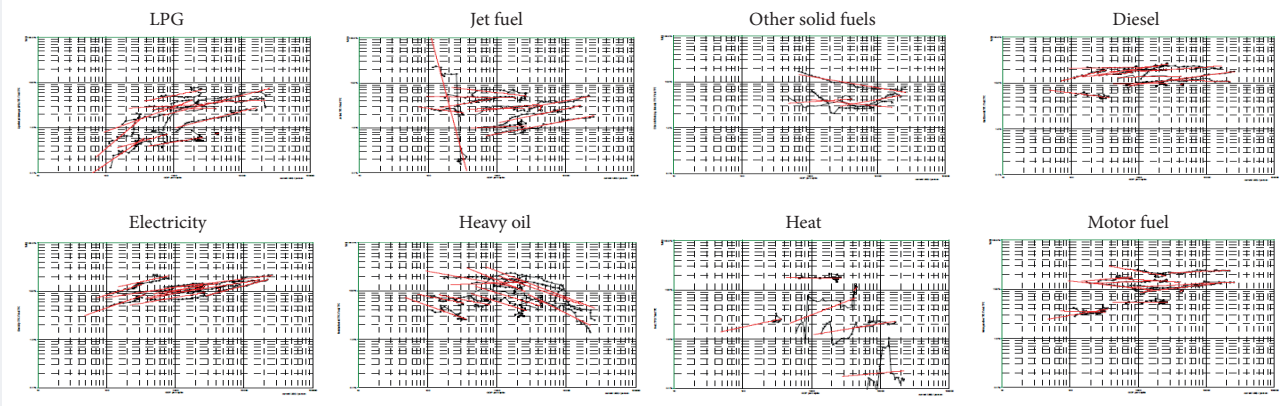
- a slowing down in the decline of coal,
- an acceleration of the decline of oil products,
- the cessation of gas growth,
- a steady increase in electricity use,
- the beginning of an increase in other solid fuels such as biomass,
- a very strong slowdown in the increase of heat use;
- an acceleration of heavy oil consumption for oil products,
- the moderate continuation of petrol and (lower) diesel growth,
- a strong slowdown in LPG growth in more developed countries,
- a decrease in growth for jet fuel everywhere.

Conclusions

Global change is a long-term and complex evolutionary procedure. Given that, it is welcome to find any reliable quantitative orientation, namely a corroboration of systemic long-term trends with global relevance. Such trends can support any of the existing methods for scenario writing, independent of the underlying assumptions, for example, such methods include:

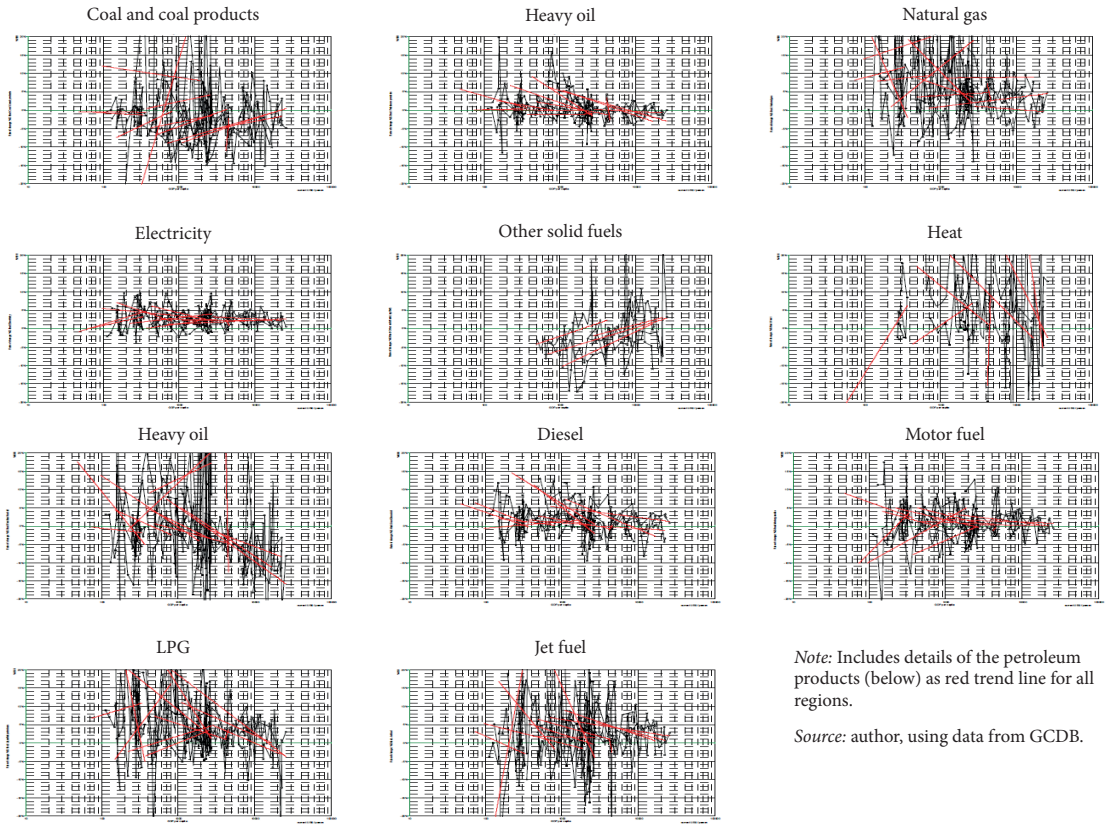
- a cyclic or exponentially growing economy,
- a steady or transition-driven historic development,
- a paradigm leaning toward ever widening or narrowing economic gaps between population groups,
- a narrative versus formulaic style for expressing historiographic and futuristic convictions.

Figure 23. **Share of Energy Use by Individual Energy Sources**



Note: Includes the detailed breakdown of petroleum products (below) as red trend line for all regions.
Source: author, using data from GCDB.

Figure 24. **Rate of Increase in the Share of Energy Use by Individual Energy Sources**



Note: Includes details of the petroleum products (below) as red trend line for all regions.

Source: author, using data from GCDB.

In this wide existing paradigmatic context, the GCDB method (on the quantitative basis of the Global Change Data Base with its expandable 2,500 primary data sets for all countries) sets out to provide an analysis of multiple, non-linear, unpredictable, and stunning trends in economy, energy and land use on a per-country level. This article suggested several trends in the domains of energy demand and supply, energy efficiency and the intensity of its use, change in the fuel mix, economic sector composition, sectoral energy demand and supply, and, finally, changes in all of the above-mentioned change rates. Detailed trends were presented as images and texts.

At first glance, we see that growth rates of global energy demand will decline. This result is stable with regard to all energy types: the peaks of coal, oil, and gas seems to be over soon — in this sequence of energy types. Today already "peak oil" is a well-known phrase.

A suitable counterstrategy against the detected megatrends which threaten the fossil economic basis of any country strongly relying on oil, gas, and coal (such as Russia or some Central Asian countries), is to promote the production of decisively renewable energy and its integration into national grids — namely biomass, solar,and wind.

A second look, however, brings us beyond the mere contemplation of "trends" which tacitly rely on the assumption that world history proceeds in a linear or exponential manner. A thorough analysis of evolutionary paradigms (Ahamer, 2019) shows that many combinations between cyclic and trend-oriented exist and that history does not at all flow in the direction which could ever be expressed by stringent formulae, not even by exponential or sinus curves. Rather, the CEBM diagnosis suggests transitions as governing dynamic pattern in techno-socio-economic evolution. Examples are, starting with already well-known transitions:

- the *population* transition,
- the *deforestation* transition or land-use transition,
- the transition among several *energy sources* which have their corresponding main pollutants, and
- with regard to *economy* as a whole, a steady historic shift away from the agricultural sector towards industrial sectors and onwards to service

sectors in various types of graphic representations

As to the *energy transition*: which is the main focus of our article, steady lowering of the increase rate of final energy consumption (E_{final}) along historic evolution; this is one of the strongest existing trends overall. This diagnosis is corroborated by the variable "final energy consumption per capita (E_{final}/cap)" coming into saturation which can be still better visualised by its growth rates. The most striking diagnosis is found for the strongly decreasing variable *energy intensity*, i.e., the required final energy consumption for producing a unit of value added (E_{final}/GDP; and its growth rate). This energy transition (in the sense of a strategic retraction from fossil fuels and reorientation towards renewable energies) is actually the focus of all country's present climate strategies, and is still more speeded up by the worsening geo-political issues, calling from energy supply independence from incalculable authoritarian regimes.

As to *transitions within energy sectors* and *fuels*, among a complex overall picture, several general trends can be identified, including: (i) away from (dirty, emission-rich) primary fuels such as coal and crude oil) toward consumer-oriented and refined fuels such as electricity, heat, LPG and jet fuel and (ii) away from heavy sectors, such as (especiallye steel) industry and agriculture toward service sectors.

All these transitions are observable principally in all countries, while the historic time of their onset varies considerably, which can even be several centuries. In order to 'normalize' these effects, the historic time is often replaced by a country's economic level (GDP/capita) in order to depict a proxy variable for 'evolutionary time'.

Therefore, evolution is seen here as a sequence of transitions, and was called "*blossoming evolution*" by this author earlier (Ahamer, 2019). This paradigm means that (additionally to a mainly evolutionary dynamic) state transitions between distinct socioeconomic systems take place in world history (Christian, 2018) while each of them maintains a steady-state equilibrium (until it becomes systemically unstable) while functioning on the basis of a set of "natural laws" (e.g., those of power vertical as opposed those of democratic respect and self-responsibility). Each such socioeconomic system produced its own characteristic rationality, laws and ethics, as could be perceived throughout history (Küstenmacher et al., 2010). According to long-term historical observations, despite some (and large-scale) deviations, the world is evolving towards a more democratic structure based on dialogue and mutual respect, which is consistent with the provisions of the theory of "*blossoming evolution*".

To sum up, the Global Change Data Base (GCDB) method is a suitable tool for detecting trends and changes in trends in the global energy system, thus providing a better understanding of its global dynamic behaviour.

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Consistency Principle: Theory and Empirical Evidence

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Abstract

The article verifies one of the principles of the general theory of social development, which is called the principle of consistency. According to this principle, the economic growth rate positively depends not only upon the level of technological development, institutions, and culture, but also upon the degree of consistency between these factors. This hypothesis was tested by constructing econometric models on a sample of 154 countries. The output variable is the rate of GDP growth, and the explanatory factors are technology, institutions, and culture. To quantify the latter, the corresponding proxy variables were used: labor productivity, the Doing Business index, and the Corruption Perceptions Index. The constructed models are fixed-effect models, and the coefficients of the explanatory variables are determined by adjusting the variance-covariance matrices. Empirical evidence has confirmed the validity of the principle of consistency for the group of "rich" countries with upper middle income, and have not been confirmed for the group of "poor" countries with lower middle income. The obtained result was interpreted in terms of the concept of a narrow corridor called Acemoglu–Robinson, the concept of structural competition and the theory of self-organization. It is shown that the consistency principle acts as a necessary condition for the appearance of the Red Queen effect in the Acemoglu–Robinson concept.

Keywords: the principle of consistency; narrow corridor concept; Red Queen effect

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Introduction

The modern general social evolution theory attempts to interpret the driving forces and mechanisms of human development or degradation, including such aspects as economic growth rates. However, many of the results obtained in this field are hypothetical and require empirical verification. Most present-day social evolution theories tend to be based on system-wide approaches that are commonly applied for complex systems of any nature. One such approach is represented by the polycausal social evolution (PCSE) concept (Balatsky, 2021a) based, in contrast to the traditional causal optics, on the structural principle. The core PCSE aspect is competition resulting from the self-assembly of a social system. Its effectiveness is manifested in the consistency principle (CP), according to which social progress and economic growth stem from the interaction of technological, institutional, and cultural development factors.

The PCSE concept is in line with modern approaches to modeling complex systems, and at a qualitative level its postulates are quite consistent with the observed phenomena (Balatsky, 2021a). However, in the absence of a reliable empirical basis, the PCSE remains a purely hypothetical analytical construct. The purpose of this paper is to formalize the CP and econometrically verify it using large arrays of statistical data. The general hypothesis of the study can be formulated as follows: a country's economic growth rate positively correlates with the consistency in the development of three groups of factors: cultural, institutional, and technological ones; an imbalance in the development of the three above areas hinders economic growth.

The Consistency Principle in Social Development Theory

Different variations of the CP have been discussed in the academic literature for quite a long time. Almost all researchers note four social development factors: technology, institutions, culture, and geography; what is different is which of them is considered the key one at a particular development stage. However, these factors' subsequent interactions were taken into account by practically all authors. For example, according to Marx, technology was the dominant development factor, while the CP manifested in the match between "productive forces" (technologies and workers[1]) and "production relations" (institutions) (Marx, Engels, 1960). Max Weber linked development to a spiritual factor, namely Protestant ethics (culture) to which institutions and technologies adapted (Weber, 1930). For Francis Fukuyama, the cultural factor of trust underlies all social and economic change (Fukuyama, 1995). Lev Gumilev believed the level of the nation's "passionarity" (culture) determined by geography to be the source of historical development, which adapts the surrounding landscape by means of technology to match its needs (Gumilev, 2016).

Correlation between these factors is a key aspect of modern approaches in the social development theory. For example, (Welzel, 2013; Lal, 1998; Petrakis, 2014) pay special attention to emancipatory values (culture as individuals' aspiration for freedom), which give rise to effective institutions, release people's creative abilities, and lead to technological progress. In the framework of this approach, the concept of "culture as an economy" (Ramocka, 2010) was developed. A broad understanding of culture (Karimzadi, 2019; Van Der Borg, Russo, 2005) implies considering its "history-conditioned exogenous component": assessing and analyzing the correlation between this component and the regional economic development (in particular, in Europe) (Tabellini, 2010)). Despite similar natural conditions, US regions populated by Catholic German settlers employed a completely different model of agriculture, had a very different property structure and female fertility rate compared to colonists in other ethnic groups, and these differences remained in place for more than a century (Guiso et al., 2006).

According to Jared Diamond, all cultures, and their respective institutions and technologies are the result of adapting to basic geographic (natural) factors (Diamond, 1997). There is empirical evidence that suggests that the dominance of market ("Western") or non-market ("non-Western") institutions in different countries is determined by a narrow set of climatic characteristics (Kirdina-Chandler, 2018).

Daron Acemoğlu and James Robinson assign a crucial role in social development to the institutional factor directly reflected in a society's technological and cultural models (Acemoglu, Robinson, 2012; North et al., 2009). In a later study they supplemented their institution formation theory with a mechanism of (mis)match in the development of centralized power and civil society (Acemoglu, Robinson, 2019).

A broader view of the CP as interconnected changes in several groups of social development factors (institutional, technological, cultural ones, etc.) was gradually developed by Victor Polterovich (Polterovich, 2002; Polterovich, 2016a). He sees the mechanisms for coordinating actors' interactions as the basis of modern social evolution theory (Polterovich, 2016b), with the assumption of related

[1] Marx's productive forces mean not only technologies (labour tools), but also workers with their knowledge and experience. However, growth of productive forces is driven specifically by development of technology (production capital).

changes in various other factor groups (Polterovich, 2018a, 2018b). In other studies, the CP was initially described as a conformity (concurrence) principle: "...economic growth requires effective institutions, but there also must be rather strict conformity between the technological, institutional, and cultural development levels" (Balatsky, Pliskevich, 2017). Somewhat later the CP was finalized in the following form: "economic growth rates are positively correlated with the degree of consistency between the level of wellbeing, and the development of technological, institutional, and cultural factors in the country. On the contrary, a mismatch between the maturity of these factors negatively affects economic growth" (Balatsky, 2021b). The cited work attempted to formalize and qualitatively verify the CP on the basis of several countries' modernization experiences. However, no quantitative verification of the CP concept has yet been undertaken, which leaves the question of its validity open.

As for the terminology, since in natural sciences, principles and laws are very much universal, the CP must hold true always under any conditions. However, in social sciences, such terms lose their rigor, and under some conditions allow for certain deviations from the given parameters. Hereinafter we will adhere to a less rigorous social interpretation of the CP; this would require renaming it into a *synchronization mechanism*, but it seems appropriate to maintain terminological continuity.

Another limitation for this study is the fact that stating the CP holds or does not hold true can only be based on reliable observations of such highly abstract phenomena as culture, institutions, and technologies. In empirical studies, these categories are replaced by specific indicators which only partially reflect the phenomenon being measured. Thus, even a definitely established principle by means of econometric calculations, CP violation does not provide a final and exhaustive answer to the posed question. There is always a possibility that the use of better variables would affect the effect in question. The subsequent conclusions should be seen with this caveat in mind.

Finding Proxy Variables: An Overview of Approaches

Assessing the CP in the proposed wording turns out to be a sufficiently difficult task, since it requires building an econometric model of economic growth with generalized variables such as culture, institutions, and technologies (the geographical factor was excluded from consideration, and wellbeing taken into account indirectly). Next, we will consider the statistical aggregates which can serve as proxy variables for these three groups of factors.

Starting with Robert Solow's work of the 1950s (Solow, 1956; 1957), technological progress has become an integral element in the majority of social development models, assessed in many different ways. The traditional measurement mechanism based on calculating total factor productivity is subject to well-substantiated criticism (Van Beveren, 2012; Reati, 2001). A popular measure of technological progress is the number of patents issued for inventions, and of innovations brought to market (Acs et al., 2002). Statistical data analysis provides increasingly more evidence for such an obvious consequence of technological development as labor productivity (LP) growth (Fagerberg, 2000; Giordano et al., 2017). The choice of this proxy variable for technological progress is usually determined by the time period under consideration, the availability and quality of data, and the specific features of the economic growth model applied (Sargent, Rodriguez, 2000). This approach seems to be optimal for assessing the level of production technologies.

The institutional factor of economic growth has attracted close attention from researchers since the early 1990s. The US economist Douglas North proposed a theoretical framework for analyzing the impact of institutions' quality on economic development based on incentives (North, 1991, 2010). Dani Rodrik, on the contrary, believed institutions' impact on aggregate output growth was indirect, and only took it into account as an exogenous economic development factor (Rodrik, 2003). Subsequent discussions focused on identifying the most effective institution types, and comparing their impact with that of geographic, climatic, and socio-cultural factors (Cvetanović et al., 2019; Urbano et al., 2019).

There is complete consensus among economists regarding the role the quality of the institutional environment plays in accelerating economic growth. Pluralism of approaches is mainly observed regarding specific ways of quantifying the institutional factor. The most popular ones are based on using composite indices combining several assessment areas (aspects of social life) with quantitative and qualitative indicators (Tvaronavičienė, Grybaitė, 2012). Typically, such indices are applied to four types of institutions: legal (Heritage Foundation Index of Economic Freedom, International Country Risk Guide, World Bank Worldwide Governance Indicators), regulatory (EBRD Transition Indicators), human capital development (UN Human Development Indicators, World Bank Knowledge Economy Index), and economic coordination and risk sharing ones (credit ratings) (Freinkman et al., 2009). The Ease of Doing Business Index (DB) turned out to be very suitable for use in growth models due to its universal nature and wide coverage of institution types (Haidar, 2012; Messaoud, Teheni, 2014). Some mod-

els use several institution quality indices (see, e.g., (Vanino, Lee, 2018)). The DB index appears to be the most effective institution quality indicator meeting the requirements for proxy variables.

Weber's idea of cultural determinants' role in economic development found wide application in macroeconomic models. Assessing cultural factors, finding the best ways to adequately quantify them, and analyzing their correlation with the state of national economy is seen as particularly important in present-day studies. For example, the World Values Survey extensive statistical database became the basis of the Achievement Motivation Index which reflects the values parents instill in their children: resolve and parsimony versus obedience and religiousness (Granato et al., 1996). A sample of 25 countries was analyzed to reveal the positive impact of a "can do" mindset on average economic growth rates. The same results were obtained when such people's qualities as independence and responsibility were included in the value index (Marini, 2004). Similar conclusions were made regarding the respondents' values: trust, respect, and personal freedom turned out to have a positive correlation with the average economic dynamics, while obedience had a negative one (Tabellini, 2010). Generally, linking the values studied in the framework of major surveys (such as the European Values Study (EVS), the Dimension Data Matrix (Hofstede data set), the GLOBE Project, the Schwartz Value Survey (SVS), etc.) with the overall cultural level (Masella et al., 2019; Petrakis, 2014) has become a common feature of macroeconomic models. At the same time the sporadic nature of surveys significantly limits the temporal and geographical scope of the analysis. A proxy variable reflecting more frequent observations may help compensate for the incomplete data on the cultural level of the population.

Values and attitudes affect almost all spheres of life. In the economy, their role is reflected by the level of corruption. In societies with blurred social tenets and a tolerant, or even positive attitude towards illegal ways of accumulating wealth or obtaining benefits, a so-called "corruption culture" emerges, which is reproduced from generation to generation (Hauk, Saez-Marti, 2002). This thesis has been repeatedly confirmed by abundant empirical evidence. In particular, cultural factors expressed in the results of value surveys in non-communist countries explain about 75% of the variance in the Corruption Perceptions Index (CPI) values (Sandholtz, Taagepera, 2005). A strong positive correlation was established between the CPI value and people's sharing values such as risk and uncertainty aversion, masculinity, and power distance (Husted, 1999). The opposite (corruption deterring) effect was revealed for such values as social trust and respect for others, while individualism and leniency turn out to be pro-corruption factors (Mornah, Macdermott, 2018). Correlation between the level of corruption and cultural norms is manifested not only at the macro-level, but also for individuals and enterprises (Agyei-Mensah, Buertey, 2019; Barr, Serra, 2010). Despite all its limitations, the CPI can be seen as a valid proxy variable for the cultural level of the public.

Various combinations of the technology-institutions-culture triad have proven to be effective in modeling economic growth. According to Guido Tabellini's calculations, institutions and values historically prevailing in five European countries turned out to be strongly correlated with the economic growth rates (Tabellini, 2010). Another study showed that unit value added created by small and medium-sized enterprises is indirectly correlated with the average per capita GDP of these firms' country of residence, through informal and formal institutions (Ostapenko, 2015). The latter were measured using the Global Competitiveness Index (Institutions pillar) developed by the World Economic Forum, the Rule of Law Index, and the share of the shadow economy; informal institutions were measured via social norms and values. Modeling the impact of the Index of Economic Freedom and of a set of values revealed the strongest positive correlation when these factors are combined (multiplying the variables in the regression equation), though individually they also proved to be important in almost all specifications (Mathers, Williamson, 2011). Another study demonstrated a negative impact of corruption on economic growth through the erosion of the political system and violation of people's rights (Mo, 2001). This thesis was confirmed in (Dridi, 2013) on a larger sample.

Thus, the approach which recognizes the importance of all three elements under consideration (institutions, culture, and technological progress) prevails in studying economic growth factors. However, their individual impact and multiplicative effect in specific cases may vary. One of the main problems with economic growth models is the endogeneity of variables (Marini, 2016). Various tools are applied to solve it: explanatory regressor lags; the instrumental variables method (Tabellini, 2010); structural equation modeling (Ostapenko, 2015); fixed effect panel data modeling (Góes, 2016); the method of moments (Nawaz, 2015). Depending on the combination of factors and theoretical constructs, the correlation between them (and the conclusions about causal relationships) vary greatly. The initial national or regional sample also significantly affects the robustness of results. In other words, national development models play an important role in modeling economic growth.

Generally, constructing an econometric model to explain economic growth rates in terms of three major groups of factors (cultural, institutional, and

technological ones), measured by proxy variables such as LP, DB, and CPI, can be seen if not as a standard, then a quite common approach.

Formalizing the Consistency Principle and Source Data

The general hypothesis regarding the CP which is being tested here can be formulated as follows: economic growth rates are positively correlated with the degree of consistency of such factors as the level of the country's *wellbeing,* and its *technological, institutional,* and *cultural* development (Balatsky, 2021b). A truncated set of factors will be considered below, with wellbeing and geographical characteristics excluded. The last group of factors mainly affects countries' social evolution at early stages: in catching-up countries actively borrowing institutions and technologies, climate-related features are overwhelmed by other economic growth determinants (Polterovich, 2018a). As for the wellbeing factor, it will be taken into account indirectly - through the differences in the sample of studied countries.

Due to the highly abstract nature of such basic concepts as technologies, institutions, and culture we will briefly explain their meaning in the context of this study. Institutions mean social interaction mechanisms, or behavioral norms; culture means social values, ideals, and aspirations; and technology means all production process components including equipment and control systems. These very much notional definitions are still consistent with the modern scientific approaches, to an extent sufficient for meaningful analysis.

Taking into account the above reservations, in general terms the CP can be formalized as follows (Balatsky, 2021b):

$$g = m(K, I, T)\, f(K, I, T), \quad (1)$$

where K is the average level of the country population's culture; T is the average level of the national economy's technological development; I is the average level of institutions' development (efficiency); g is the economic growth rate; and m is a metric of factors K, T, and I consistency.

The economic growth model (1) is a modified production function where economic activity is determined by labor, capital, and institutional productivity (f=f(K,I,T)), with an added accelerator m that reflects their mutual consistency (m=m(K,I,T)). Extending the traditional growth model in this way allows one to reconsider the hypothesis of a high, or even unlimited interchangeability of macro-factors in favor of their interdependence and complementarity.

Though function (1) can also be represented in an equivalent additive form, we will use it in a multiplicative one:

$$g = m(K, I, T) + f(K, I, T). \quad (2)$$

If instead of the macro-factors consistency metric we use the opposite metric of their mismatch D=D(K,I,T), equation (2) will look as follows:

$$g = -D(K, I, T) + f(K, I, T). \quad (3)$$

Any of the known distance metrics can serve as a measure of mismatch. To avoid ambiguity, we take D=D(K,I,T) as the sum of deviations from the arithmetic mean of the three factors (M), as the closest analogue of the dispersion index:

$$D = |K - M| + |I - M| + |T - M|, \quad (4)$$

$$M = (K + I + T)/3. \quad (5)$$

Equations (2) and (3) are equivalent, which becomes especially evident if, for example, coefficients m=–D (or m=1/D) are applied. For technical reasons form (3) was chosen as preferable.

Since the factors K, I, and T have completely different measuring units and value ranges, in the econometric model they are normalized as follows:

$$K=(PK-PK_{min})/(PK_{max}-PK_{min}),$$

where PK is proxy variable of the cultural level in a particular country, while PK_{max} and PK_{min} are the reference maximum and minimum values of this variable in the analyzed sample of countries; the indicators I and T are normalized in a similar way.

The mismatch coefficient D is calculated for the factors' normalized values. In which area should, for example, the PK factor be analyzed, is decided on the basis of country sample that allows one to set the interval (PK_{min}; PK_{max}); then the proxy variable PK is converted to a comparable scale, in fractions (0; 1) or in percentages (0; 100) .

To test the general hypothesis about CP validity, econometric dependence (3) must be constructed and the parameters of the desired model assessed. For convenience, linear function (3) is presented as follows:

$$g_i = \rho_i + \alpha K_i + \beta I^i + \gamma T_i - \theta D_i + \psi_i. \quad (6)$$

where ρ, α, β, γ, θ and σ are parameters measuring each factor group's impact, ψ is random error, and i is country index.

Verifying the CP requires compliance with the *a priori* conditions α>0, β>0, γ>0, and θ>0. In this case, an increase in the level of people's culture, technological development, and the effectiveness of institutions leads to an increase in the economic growth rate, while, on the contrary, an imbalance of these three factors slows the growth down. Thus, the CP is valid if the four parameters in the econometric dependence (6) have positive values. This is the hypothesis that will be tested below.

As shown in the previous section, generalized factor groups such as culture, institutions, and technolo-

gies can be sufficiently accurately expressed by the corresponding proxy variables:

g→GDP; T→LP; I→DB; K→CPI,

where GDP is the annual GDP growth rate at constant prices in local currency[2]; LP is labor productivity (GDP per employee[3]); DB is the World Bank's Ease of Doing Business Index (ranging from 0 to 100)[4]; and CPI is the Corruption Perceptions Index (ranging from 0 to 100)[5].

Though the selected proxy variables are notional, and do not reflect the relevant factors in their entirety and objective complexity, in the long term their dynamics coincide. For example, technological progress increases labor productivity, while the latter's decline indicates profound flaws in innovation activities. A favorable business environment also does not fully reflect the country's institutional complexity, but this does not mean the business climate can improve with poor-quality institutions. Similarly, the level of corruption certainly does not reflect the entire cultural diversity, but a general increase of the latter leads to a natural reduction in the scale of corruption. Thus, these proxy variables as reduced indicators of the factor groups under consideration are quite suitable for establishing the presence or absence of intra-system correlations.

A data array covering 154 countries from 2012 to 2019 was used in the econometric calculations; the total number of observations was 1,232. The use of panel data was due to the need to maximize the sample size. The relatively short time interval for such calculations is due to the limited availability of data on the CPI indicator: in 2012 the methodology for compiling it was changed so much that correct comparisons with data for previous periods became impossible.[6] The methods applied in subsequent calculations to take into account the time factor have largely neutralized the cycles in the variables' dynamics. The analysis showed that the proxy variables chosen for the model were sufficiently sensitive, and to a certain extent susceptible to cycles; this allowed for synchronizing all variables over the economic cycle stages (which would not be guaranteed for less flexible culture and institutions proxy variables).

Due to the heterogeneity of the initial set of countries, they were broken down into four groups according to the World Bank's per capita income criterion[7]: high income countries, upper middle income countries, lower middle income countries, and low income countries) (Table 1).

Further aggregation allowed us to merge the four groups of countries into two: rich ones (all countries with higher than middle income) and poor ones (lower than middle income) (Table 1). Reducing the number of analysis objects to two allowed us, firstly, to obtain more firm statistical results, and secondly, simplify the interpretation of the existing dichotomy between country groups.

During the time period under consideration some countries in the sample moved from one group to another. To maintain the data panel's integrity, a country was included in a particular income group on the basis of 2019 data; accordingly, each country remained in the same group throughout the entire time interval. This assumption did not significantly distort the actual picture, since only 12 out of 154 countries changed their group during the period under review; two of them fluctuated around the border, and only six remained in the new group for more than two years. The characteristics of the initial data set are presented in Table 2.

The LP indicator was initially logarithmized (ln(LP)) to smooth over the excessive technological gap between countries. A similar order of other factors' values allows one to use it in the framework of a single econometric model. Though wellbeing was not included in the number of the model's regressors, the very division of countries into rich and poor allowed for implicitly taking it into account in the analysis of the calculation results.

Results of Empirical Calculations

With the notations described above, and after preliminary calculations the econometric dependence took the following form:

$$GDP_{i,t} = (\nu + \mu_i + \lambda_t) + \alpha CPI_{i,t} + \beta DB_{i,t} + \gamma(ln(LP_{i,t})) + \theta D_{i,t} + \psi_{i,t} \quad (7)$$

Equation (7) takes into account the transition to panel data, which allowed for including, along with the country index i (6), the time index t; in parentheses the model constant comprises the components μ_i and λ_t: unobserved country-specific and temporal effects are measured with the corresponding dummy variables. Testing the CP for linear regression (7) requires compliance with the following

[2] https://data.worldbank.org/indicator/NY.GDP.MKTP.KD.ZG, accessed on 21.11.2021.

[3] https://www.ilo.org/shinyapps/bulkexplorer30/?lang=en&segment=indicator&id=GDP_211P_NOC_NB_A, accessed on 21.11.2021.

[4] https://russian.doingbusiness.org/ru/data, accessed on 21.11.2021.

[5] https://www.transparency.org/en/cpi/2020/index/nzl, accessed on 21.11.2021.

[6] https://www.transparency.org/files/content/pressrelease/2012_CPITechnicalMethodologyNote_EMBARGO_EN.pdf, accessed on 21.11.2021.

[7] https://datatopics.worldbank.org/world-development-indicators/the-world-by-income-and-region.html#:~:text=The%20World%20Bank%20classifies%20economies,%2Dmiddle%2C%20and%20high%20income, accessed on 21.11.2021.

conditions: $\alpha>0$, $\beta>0$, $\gamma>0$, $\theta<0$; the sign of the last parameter is inverted due to the traditional way of writing econometric models (7).

At the first stage of model calibration, the entire sample was tested to identify the most relevant panel data analysis technique. For all sample types, the standard F-test showed that the fixed effects model was preferable to the pooled regression. The Hausman Test confirmed the fixed effects model's superiority over the random effects model. At the second stage, the Breusch-Godfrey test revealed heteroscedasticity in the model, which obliged us to use a robust to heteroscedasticity covariance-dispersion matrix in line with the Arellano method (HC0 type) (Arellano, 1987). Thus, all the constructed models are fixed effects ones and the explanatory variables' coefficients were calculated using covariance-dispersion matrices.

Given the breakdown of countries into two groups, econometric models for each group and for the entire sample were built, on the basis of a single specification (7). Calculation results for countries which remained in the same income group are presented in Table 3.

Since some countries in the initial sample changed their income group during the period under review, it should be checked how significantly this affected the calculation results. For this purpose, model (7) was evaluated for countries whose income group changed; the calculation results are presented in Table 4.

Comparing the results presented in Tables 3 and 4 shows invariance of the model calculations, while the discrepancies in the quantitative estimates turned out to be negligible. Therefore, the identified correlations can be seen as sufficiently objective and stable.

A fixed effects econometric model was built to set the model parameters, which has automatically eliminated the endogeneity problem. To make sure this issue was dealt with, calculations were carried out taking into account annual lag for all regressors, and for all regressors except the LP. The results turned out to be statistically unsatisfactory, which once again confirmed the initial hypothesis that the selected proxy variables were sufficiently dynamic to build a model even for relatively short time intervals.

The statistical characteristics of the model for the rich countries group confirm its adequacy. This conclusion indicates the non-random nature of the established correlations, especially taking into account the specifics of the constructed dependence where a highly dynamic and volatile output characteristic (GDP growth rate) is determined by cumulative conservative factors (technologies, institutions, culture). This confirms relevance of the chosen proxy

Table 1. **Country groups by per capita income**

Group number	Country group	Number of countries
1	High income	49
2	Upper middle income	39
3	Lower middle income	40
4	Low income	26
5	Rich countries (No 1 + No 2)	88
6	Poor countries (No 3 + No 4)	66
7	Total (No 5 + No 6)	154

Source: authors.

Table 2. **Descriptive statistics of the model variables**

Parameters	Variables				
	GDP	LP	DB	CPI	D
Average	3.4	46290.2	62.3	44.8	0.5
Standard deviation	3.5	40976.8	12.8	19.4	0.2
Lowest value	–36.4	1762.9	29.4	8.0	0.0
Highest value	25.2	249867.8	88.7	92.0	0.9

Source: authors.

Table 3. **Characteristics of econometric models for countries which remained in the same income groups**

Factors (coefficients)	Entire country sample	Rich countries	Poor countries
ln(LP) (γ)	9.36**	6.35*	14.63**
DB (β)	0.11	0.43***	–0.32*
CPI (α)	0.04*	0.07**	–0.10
D (θ)	–6.96	–14.22*	9.17*
Statistical characteristics			
N	1232	704	528
R^2	0.05	0.13	0.08
F-test	4.54***	6.33***	3.79***
Hausman Test	67.06***	72.80***	39.50***
BG-test	168.23***	102.69***	69.20***

Significance of regression coefficients: *** (0.01); ** (0.05); * (0.1).
Source: authors.

Table 4. **Characteristics of econometric models for countries whose income group changed**

Factors (coefficients)	Entire country sample	Rich countries	Poor countries
ln(LP) (γ)	9.36**	5.30*	14.45***
DB (β)	0.11	0.44***	–0.35***
CPI (α)	0.04*	0.07**	–0.10
D (θ)	–6.96	–15.01**	10.77***
Statistical characteristics			
N	1232	708	524
R^2	0.05	0.12	0.08

Significance of regression coefficients: *** (0.01); ** (0.05); * (0.1).
Source: authors.

variables for the three groups of factors under consideration. The use of different variable types (the output GDP characteristic is a flow (current annual value), while the regressors LP, DB, CPI, and D are stocks (accumulated over many years)) determines the low explanatory power of model (7). To increase the determination coefficient, control variables for fixed assets and employment should be introduced. However, this exceeds this paper's goal which is testing the general CP hypothesis, not building an applied model for subsequent analytical calculations. In part, country and temporary dummy variables played the role of control variables.

As noted earlier, testing the CP involves obtaining significant regression coefficients with signs $\alpha>0$, $\beta>0$, $\gamma>0$, $\theta<0$. Based on this, the obtained results allow to draw the following conclusions.

Firstly, the calculations confirm the need to split the total country array into two income groups. Indeed, the initial heterogeneous sample yielded the correct signs for all regression coefficients, but the institutional factor and the CP turned out to be insignificant, which does not give grounds to see the CP as absolutely universal and unconditional. Its effect and strength depend on the country's development level, which was the reason for introducing the two country groups.

Secondly, the CP holds true for rich countries but not for poor ones. If for the first group all model (7) coefficients pass the sign test and are significant, for the second group, three of the four regressors have an inverted sign, and one of them (culture) is not significant. Thus, the CP acts as an evolutionary mechanism, and becomes true as the country develops. Also, a kind of civilizational abyss lies between rich and poor countries. If in the former a mechanism for coordinating technological, cultural, and institutional achievements is at work, in the latter the said factors remain out of sync, and even contradict each other.

Thirdly, a common factor for all countries is production technology, which positively and sufficiently strongly affects economic growth. On the contrary, institutional, cultural, and CP-related factors divide rich and poor countries: in catching-up nations economic growth is more effectively supported by authoritarian government systems than by modern democratic institutions. The successful post-war development in Asian countries is a convincing confirmation of this conclusion.

Fourthly, institutions and culture act as fine-tuning tools, in rich countries in a positive way, and in poor ones negatively. In absolute terms the impact of these factor groups is insignificant and does not define economic growth.

Fifthly, in rich countries the main development driver is precisely the CP, as a mechanism integrating all aspects of social life, while poor countries mainly rely on technological advances. This once again reveals the fundamental difference in the development models of catching up and leading countries.

Discussion of the Results

The Wealth Factor

In the proposed econometric models, the wellbeing factor was taken into account by clustering countries into two groups. The wellbeing factor determines the dichotomy of the CP regime. To illustrate these differences, let us consider the data in Table 5.

The lower bound of high-income countries is about 12 times higher than the upper bound of low-income countries, which indicates a wide gap due to the radically different modes of integrating the three factor groups: technological, institutional, and cultural ones. The above estimates are averages, while the gap in the extreme values is even more drastic. For example, in 2019 per capita income in Switzerland was 314.1 times higher than in Burundi. It is hardly surprising that countries divided by such a gap in wellbeing levels have completely different self-organization mechanisms, which is confirmed by the econometric models (Tables 3–4). In poor societies, the level of self-awareness, including that of the ruling elites, is extremely low, which makes maintaining an effective dialogue impossible. No public associations can be established in such environments, or people's interests protected.

For countries where people are concerned with physical survival, the need to coordinate culture, institutions, and technologies is irrelevant. As the wellbeing increases, the public's self-awareness and activity increase too, which pressures the ruling elites to regulate social life more efficiently. The CP may apply in poor countries also, but the econometric dependences in Tables 3–4 indicate that it can be quantified only in developed economies. The per capita income level which allows one to speak about the CP is by no means unreasonably high: more than half of the 154 studied countries fall into the rich group with a developed mechanism for coordinating culture, institutions, and technologies.

The CP allows to take a fresh look at the BRICS group of countries: Brazil, Russia, China, and South Africa can be classified as rich nations with fairly mature mechanisms for coordinating technological, institutional and cultural reproduction, while India stands out as a member of the poor countries group. Accordingly, it still lacks prerequisites for the CP to apply, which may slow down the country's future development.

Table 5. **Critical gross per capita national income values for different country groups (*thousand USD*)**

Years	2012	2013	2014	2015	2016	2017	2018	2019
Upper bound of low-income countries	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Medium income	4.1	4.1	4.1	4.0	3.9	3.9	3.9	4.0
Lower bound of high-income countries	12.6	12.7	12.7	12.5	12.2	12.1	12.4	12.5
Russia, % of lower bound of high-income countries	**106.9**	**119.2**	**114.9**	**96.3**	**80.7**	**76.4**	**82.8**	**89.7**

Source: authors.

Another BRICS member, Russia, was subjected to international sanctions after 2014, the effectiveness of which has been repeatedly discussed in the literature (see, e.g., (Balatsky, 2018; Ekimova, 2018)). The CP allows for approaching this issue in a new way. Since in 2012–2019 Russia belonged in the rich countries group, after 2014 international sanctions did not push it into the poor nations' one, where the positive integration mechanisms created by economic development are either extremely weak or do not work at all. The sanctions did not cause any fundamental damage to the Russian economy or interrupt the country's development, since it already had sufficient groundwork to improve the institutions and increase political culture. At the same time, it must be noted that until 2014 inclusive Russia confidently remained in the high-income countries category, but in 2015 it has moved into the upper-middle income group where it stays to this day (Table 5). Thus, a certain loss in the former CP effectiveness can be noted.

Let us try to evaluate how the model calculation results match relevant theories. According to Acemoglu and Robinson's *narrow corridor concept* (Acemoglu, Robinson, 2019), the key to the effectiveness of the modern state (Shackled Leviathan) is political balance between it and society.[8] Translated into the terminology applied in this paper, this is the interaction of two factor groups: institutions (state) and culture (society), which in reality remain inseparable and can only be distinguished notionally. At the same time their synthesis involves merging two functionally different phenomena: content (culture), and form (institutions). People's attitudes, ideas, ideals, and behavioral models (culture) are contained in a kind of shell made of formal and informal behavior rules (institutions), which together set the cultural and institutional context in the country.

Acemoglu and Robinson's concept assumes that the multitude of effective interactions between society and the state represented by the national elites form a "narrow corridor", which can only be maintained if numerous conditions are met. If that is the case, institutions and culture synergistically reinforce each other, which in turn increases both the efficiency of the state and the opportunities for society. This process reproduces the evolutionary *Red Queen effect* which implies that society and elites need to make relentless efforts, to the limit of their abilities, to simply maintain the political status quo[9] (Acemoglu, Robinson, 2019). Otherwise, a conflict arises between the state and society, leading to the victory of either the first (despotism, or Despotic Leviathan) or the second (anarchy, or Absent Leviathan).

When elites and society are balanced, it promotes the emergence of progressive democratic institutions and increases the cultural level of the public, which allows them to support each other and achieve harmony. But if the society's self-consciousness and aspirations for freedom are not particularly strong, the elites take advantage of this to establish and strengthen institutions for suppressing civil liberties (Despotic Leviathan). If elites' self-consciousness, desire for order, and willingness to give up their privileges are insufficient, the risk of the state foundations' destruction and the emergence of chaos (Absent Leviathan) increases.

The models presented in Tables 3–4 showed that a *necessary condition* for the emergence of the Red Queen effect, and shackling the Leviathan, is a high level of wellbeing typical for the group of rich countries with a relatively high per capita income. Of the 154 countries considered, only slightly more than half fall into the "narrow corridor" of per capita income sufficient to ensure political balance between the state and society. This conclusion not only agrees with the narrow corridor concept, but clarifies it. As noted earlier, a low standard of living forces people to concentrate on survival, relegating to the background the ideas of personal and political freedom,

[8] "Narrow corridor" is graphically represented by coordinates on the "strength of society" and "strength of state" plane, reflecting the position of these two actors. There is a "narrow corridor" on the graph around the bisector, denoting the zone where the strength of the state and society is approximately equal..

[9] In Russian-language literature the "Red Queen effect" is called the "Black Queen effect"; we retain the authors' version.

and even more so of taking control over the power structures.

We emphasize that countries with a high per capita income only meet a necessary condition for achieving the Red Queen effect, but by no means a sufficient one. Various rich countries have very different political institutions, for example, Saudi Arabia, Qatar, Brunei, Kuwait, the UAE, Bahrain, and Oman on the one hand, and the US, UK, France, Switzerland, and Sweden, on the other. All these nations have the economic prerequisites for achieving political equilibrium, but only in the second subgroup this equilibrium has actually been realized. Thus, in today's world the CP applies more widely than the Red Queen effect and even acts as the first step toward achieving the latter. A sufficient condition for it is the CP holding true for the highest values of the proxy variables LP, DB, and CPI.

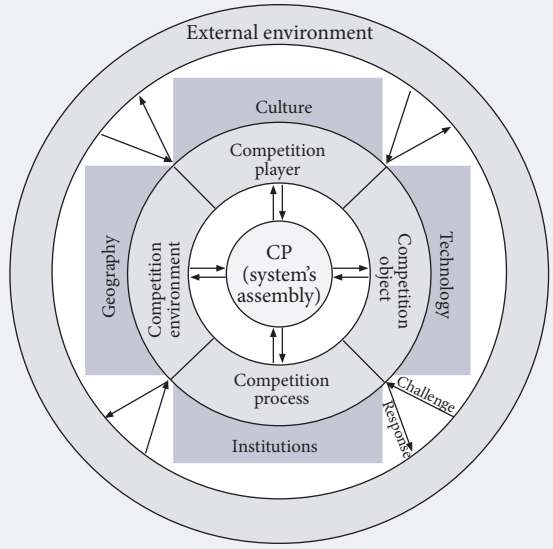
Structural Competition

The structural competition concept (Balatsky, 2021a) is based on the idea that the rate of social development depends on the efficiency of the market system. The latter includes four elements of competition: players (*who* competes), objects (*for what* and *with what* they compete), process (*how* they compete), and environment (*where* they compete), and the links between them. Players reflect the society's culture, objects — production technologies, process — institutions, and environment — the ecosystem and geographical factor.

The structural market system elements are consolidated and coordinated through market self-regulation, a higher level of which increases the efficiency of the entire social system and accelerates economic growth. Structural self-assembly of the market system is expressed through the CP, while its specific mechanisms make up the functional core of the system (Figure 1). The process of self- and re-configuration of the system is triggered by external perturbations — challenges (Toynbee, 1966) or stressors (Taleb, 2007). Its (the system's) further existence depends on how successful the society's organizational response will be.

The scheme in Figure 1 is sufficiently abstract to be interpreted at different levels: corporate, social, national, regional, and even global ones. In its current form it raises several questions. First, does the CP have the symmetrical property, when the improvement in different factor groups has a unidirectional effect on the economic growth rate? Second, what is the CP's role in the competitive mechanism? An equation describing GDP growth rate sensitivity to changes in the CPI can provide an answer to the first question:

Figure 1. **Market competition structure**



Source: authors.

$$\frac{\partial(GDP)}{\partial(CPI)} = \alpha + \theta \frac{\partial(GDP)}{\partial D} \frac{\partial D}{\partial(CPI)} \quad (8)$$

Similar equations can be applied to the other two factor groups. And, as can be seen from equation (8), in addition to the direct impact, due to the CP the macro-factor has a certain indirect effect associated with GDP's increased sensitivity to the imbalance between the macro-factor D (∂(GDP)/∂D) and the perturbation of the D imbalance by the CPI (∂D/∂(CPI)). In model (8) both of these components depend on the initial conditions, i.e., a specific country and point in time. In the end the overall impact of the three factor groups (technology, culture, and institutions) can be unidirectional or multi-vector. To be more precise, let us consider the 2019 situation in the four most indicative countries: the US, Germany, China, and Russia, which serves as a base scenario and a starting point for applied calculations. In parallel, we shall consider three scenarios in each of which one macro-factor changes by 10 percentage points, while the others remain unchanged. The calculation results are presented in Table 6.

As shown in Table 6, in 2019 among the countries under consideration, the three groups of factors were most highly balanced in the United States and were most poorly balanced in Russia. The imbalance of macro-factors in Russia was 1.8 times higher than in the US, which in itself indicates a large socioeconomic gap between the two countries. Under these circumstances the CP effect becomes funda-

Table 6. **Different factor groups' impact on economic growth rate**

Country	Scenario	D, %	ΔD, p. p.	ΔGDP, %
US	Base	43.6	–	–
	Δ[ln(LP)]	36.2	–7.4	1.7
	Δ(DB)	56.3	12.7	–1.8
	Δ(CPI)	50.2	6.6	–0.9
Germany	Base	57.9	–	–
	Δ[ln(LP)]	44.6	–13.3	2.5
	Δ(DB)	64.6	6.7	–0.9
	Δ(CPI)	64.6	6.7	–0.9
China	Base	66.6	–	–
	Δ[ln(LP)]	59.9	–6.7	1.6
	Δ(DB)	79.9	13.3	–1.8
	Δ(CPI)	68.1	1.5	–0.2
Russia	Base	77.5	–	–
	Δ[ln(LP)]	70.9	–6.6	1.6
	Δ(DB)	90.7	13.2	–1.8
	Δ(CPI)	70.8	–6.7	1.0

Source: authors.

mentally asymmetric: an improvement in production technologies in all cases has a positive effect on economic growth, while an increase in the DB and CPI values leads to an imbalance of the three factor groups and hinders growth (the only exception is Russia, which is clearly lagging behind in terms of the CPI, so its growth improves the overall situation). The CP symmetry is individual in nature, and by default absent.

The answer to the second question follows from equation (7) itself, according to which each factor group's impact is expressed directly and indirectly as shown in equation (8). Thus, the coefficient D (which reflects the CP effect) acts as a kind of competitive feedback mechanism: if market processes become one-sided and manifest in a single area only (e.g., technology), the imbalance of D begins to increase and absorbs some of the direct positive effect of this unilateral progress. Here the CP plays the role of a natural regulator of competitive processes taking place in various areas, signalling to the system that the potential of a factor group which has got ahead of others is exhausted. The ability of the state to influence each of these groups allows it to both strengthen and weaken the CP's regulatory function.

Chaos and Complexity

In recent years applying the self-organization theory to social problems became increasingly popular. The self-organiation of society in interacting with state institutions was addressed in (Nederhand et al., 2016; Edelenbos et al., 2018). The role of self-organization in the emergence of the post-capitalist culture is explored in (Escobar, 2017). The importance of this line of thought suggests the CP should be considered in terms of the chaos and complex systems theories.

The self-organization theory implies that a stable structure underlies the apparent disorder and non-linearity of processes (Mann, 1992). Similarly, the CP views the market system as a self-ordering one, consolidating its structural elements through competition. At first glance, competition generates a multitude of multidirectional market interactions. However, on a historical scale these interactions' cumulative experience changes (a) the market players themselves (culture), (b) the rules of their interaction (institutions), (c) the means of competing (technologies), and (d) the very market ecosystem (geography). It is these processes which, unfolding simultaneously, create the social fabric. Depending on the effectiveness of the competition mechanism, more and less highly developed state structures emerge.

An important aspect of the above reasoning is the non-linear nature of competition's effect on social development. A lack of it does not allow individuals' creative potential to fully come out, while its excess hinders the implementation of creative ideas; therefore, an effective competition mechanism implies finding a competitive regime optimal for the market. Spontaneous competition leads to anarchy, or, in Acemoglu and Robinson's terms, to Absent Leviathan; artificially suppressed competition gives rise to a clumsy government system inefficiently administering the economy, or Despotic Leviathan. An effective state with a large innovation potential — Shackled Leviathan — achieves the right balance between centralized public administration and market self-regulation externally manifested through the CP. Thus, the impact of competition on economic growth is non-linear, since there can be too much and too little competition. Therefore, it is important not only to nurture competitive forces but also control them, which is largely the prerogative of the state.

Perhaps the most striking example of excessive competition and the chaos it creates is the Federal Republic of Somalia, where since the early 1990s famine, civil wars and armed gang activity rage. An example of a lack of market competition is the present-day Russian Federation where big business operates in the form of monopolistic state-owned corporations, while the success of small and medium-sized enterprises depends more on their administrative competition potential and government connections than on production or technological performance. In both these cases the social system's sensitivity to innovation turned out to be low.

In the framework of the chaos and complexity theories, the role of CP seems to be quite obvious. In the early social development stages, the initial chaos is ordered by one specific dominant force, namely the geographical factor which forces people to actively explore the surrounding landscape. This period can be associated with such multidirectional events as wars, construction of irrigation facilities, internal strife, technological innovation, unification and separation of large social structures, natural disasters, epidemics, etc. At a certain stage a disorganized set of events is structured into distinct social subsystems: legal (institutions), behavioral (culture), and production (technology) ones. As they grow more complex, their importance for society and the role in making certain decisions increase. Thus, out of the primitive social chaos a (mainly) state-like order crystallizes. The subsequent development of the cultural, institutional, and technological subsystems turns the CP into a mechanism for synchronizing this development, ensuring social harmony and balance and multidirectional competition. The CP acts as a kind of anti-entropic gravitational force which does not allow the three key social subsystems to ynchronizes. Furthermore, it creates a synergy from the subtle integration of these subsystems, measured using equation (7) of the factor D. At mature social development stages, the CP acts as its self-regulation mechanism, including conscious self-regulation by the state and elites, creating and adjusting a kind of friction between various social system elements.

It is quite difficult to trace the CP's role in the emergence and historical development of society, but it becomes sufficiently obvious during the periods of civilisations' decline and fall. For example, the high level of culture in ancient India or China was not supported by adequate institutional and technological systems, which has led to their relative lagging behind the European civilization. Ancient Rome, on the contrary, with its quite perfect legal system and advanced technologies, fell into decay due to the gradual destruction of its traditional culture.

Conclusion

The diversification of social evolution theories has led to the emergence of polycausal concepts which refuse to single out one leading development factor, and consider them all as relatively equal. One such approach is the structural competition concept (Balatsky, 2021a), in which the CP plays a key role. The calculations presented above allowed for empirically verifying this principle, highlighting a structural pattern in a group of 88 relatively rich countries where economic growth rates positively depend on the balance in the development of three factor groups — cultural, institutional, and technological ones. Thus, an analytical confirmation of the structural competition concept and the CP was found. In other countries the CP may also apply, albeit in a slightly different form, so the proxy variables used here cannot measure it.

The established structural pattern highlights the issue of countries' and peoples' social evolution from a new angle: the progress must move on along a broad front, covering all aspects of social life. This requirement implies an extremely high plasticity of the social system which is capable of responding to external perturbations in time by aligning some groups of factors with others. For example, the technological modernization of the economy must be accompanied by sweeping institutional and cultural reforms. However, since each country has its own civilizational characteristics, there can be no ready-made recipes for accelerating its development. Apparently, this explains the numerous failures of progressive reforms in many countries of the world.

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Research Landscape and Trends in Corporate Foresight

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Abstract

Corporate Foresight (CF) gains increasing research interest as an efficient decision-making tool in the face of growing market uncertainty. We carried out a bibliometric analysis of the CF literature published between 2001 and 2021. The results of bibliometric analysis propose in which journals researchers should publish their papers to obtain more citations, which to cite, which keywords to use, and which references to explore. This allows managers, researchers, and practitioners to gain in-depth knowledge of CF literature.

Keywords: corporate foresight; strategic foresight; open foresight; bibliometric analysis; journals; citation.

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Introduction

Technological innovation spurs economic growth while amplifying market uncertainty and causing other "big challenges". Companies face challenges in comprehending the factors that lead to environmental change, assessing their impact on businesses, choosing options for response, and assessing the consequences of those choices (Latzer, 2009; Vecchiato, Roveda, 2010). When dealing with continuous turbulence of the external environment, the "traditional" concepts of strategic management, such as the resource-based view and capabilities theory, do not work (Vecchiato, Roveda, 2010; Rotjanakorn et al., 2020). Therefore, there is a need for strategic fit — companies need processes to keep track of the consistency and positioning of their strategy with regard to weak signals and trends, as well as the skills to create alternative scenarios for the future. Such an approach will make it possible to adjust corporate agendas for "future proofing" in a timely manner, thus gaining long-term competitive advantages (Battistella, De Toni, 2011).

The basis for the designing such strategies is offered by the Corporate Foresight (CF) toolkit (Rohrbeck, Gemünden, 2009; Vecchiato, 2015; Bereznoy, 2017). Their success depends on the ability to think holistically, create partnership networks for innovations, involve a wide range of stakeholders in the Foresight process (Ratcliffe, 2006; Wiener, Boer, 2019), and have a comprehensive understanding of the CF knowledge base, including research areas, cases.

The purpose of the paper is to understand current trends in CF research by quantitatively, computationally, and systematically reviewing the literature corpus. Previous efforts to review this field of study have been qualitative, such as (Daheim, Uerz, 2006; Rohrbeck et al., 2015; Adegbile et al., 2017; Iden et al., 2017; Gordon et al., 2020). Thus, there is a gap to be fulfilled where quantitative and computational analyses are used to identify future research patterns. This study aims to provide the first bibliometric analysis exploring corporate foresight literature. Though, it must be noted that, to our knowledge, there are already two publications that performed bibliometric analyses: on technology foresight (Gibson et al., 2018) and on regional foresight (Amini et al., 2021). However, our research will have a broader perspective. Based on this research problem three research questions were formulated:

- How has corporate foresight research changed over the last two decades?
- What is the intellectual structure of corporate foresight?
- What are the current research trends in corporate foresight literature?

Methodology

Research design and tools

To analyze and cohesively organize the knowledge base of a particular domain, a systematic literature review is often used. It implements a content analysis of a limited number of reviewed studies (most often no more than a hundred sources) (Donthu et al., 2021; Han et al., 2020). It is manually intensive, qualitative (i.e., it relies exclusively on expert judgement), and hence the results are subjective, thereby prone to bias (Zhai et al., 2021).

Another common approach, bibliometric network analysis, combines qualitative and quantitative computational methods, that is, it combines both quantitative analysis (evaluation and interpretation) and qualitative analysis (interpretation only). With its help, much larger arrays of scientific publications (about several hundred or even thousands) are processed, common research topics and directions of future research are identified (Han et al., 2020). The use of quantitative computational methods creates a more objective picture of a certain research field and makes it possible to identify links between its various branches (Han et al., 2020, Zhai et al., 2021).

Bibliometrics are used to analyze research elements such as citation, authors, and semantics using graphic elements to present the data in the form of a network map (nodes) (Gibson et al., 2018). It provides an in-depth understanding of the state-of-art and trends of the studied field. A comparison of the characteristics of each of the two approaches justifies our choice in favor of bibliometric analysis since it fully meets the objectives of our study.

There are several types of networks represented in Table 1. The metrics used to evaluate each network's node are presented in Table 2.

Each network can be divided into clusters. The division of the network into groups of individual nodes is called clustering, and those groups are called clusters. There are two types of clustering approaches: a hard clustering approach (non-overlapping clusters) and a soft clustering approach (overlapping clusters) (Chen, 2016). Using non-overlapping clusters allows for differentiating between the clusters' natures, being more efficient than using overlapping ones.

Cluster labeling is an algorithm-based approach that employs index words or terms from the article

Table 1. **Network Types Analyzed within The Study**

Network type	Code
Co-authorship network	node = author
Co-authors' institutions network	node = institution
Co-authors' countries network	node = country
Co-occuring phrases network	node = term
Co-occuring author keywords network	node = keyword
Co-ocurring subject categories	node = category
Document co-citation network	node = reference
Author co-citation network	node = cited author
Journal co-citation network	node = cited journal

Source: authors.

Table 2. **Metrics Used to Evaluate Network Nodes**

Metrics	Description
Degree of Centrality	This is the number of the relational ties of a node within a network (Donthu et al., 2021). For example, if the node is an author, the degree of centrality is the number of authors with whom one author worked.
Betweenness Centrality	According to Chen et al. (2010), each node in a network has its betweenness centrality metric. It varies from 0 to 1*. It determines how close the node is to be in the center of a path that links other nodes in the network as it measures the probability that a node is on the shortest path in the network (Chen, 2005). High betweenness centrality ratings suggest potentially revolutionary scientific articles as well as gatekeepers, responsible articles, or authors for innovation, in networks (Chen, 2006).
Burstness	Concerning the burstness of an item (reference, author, keyword, journal…), the burst value evaluates whether a particular frequency function exhibits statistically significant changes over a brief time interval within a larger timeframe. Citation analysis can use burstness to determine whether and when the citation count of a certain reference has increased (Chen et al., 2010).
Sigma	The sigma value (∑), represents a measure of scientific innovation, novelty. It selects scientific publications that are likely to contain innovative ideas based on two transformative discovery criteria, centrality, and burstiness - $(centrality+1)^{burstness}$ - (Chen et al., 2010). According to Gaggero et al. (2020), it measures the combined strength of structural and temporal properties of a node, namely, its betweenness centrality and citation burst. Higher sigma values often signify greater creativity, innovativeness, and influence (Zhang et al., 2020). In the current research, we set sigma>1.5 to represent the possible originality, innovation, and influence of a topic.

Source: authors.

titles and abstracts of each cluster (Chen et al., 2010). Clusters are automatically labeled by the selection of phrases and index terms from the cited publications in each cluster (Chen et al., 2010). These terms are ranked by three different algorithms: Log-Likelihood Ratio (LLR), Latent Semantic Indexing (LSI), and Mutual Information (MI). LLR and MI tend to represent a distinctive feature of a cluster (Chen et al., 2010). The overall structure of networks and the criteria for selecting nodes are determined using the "Q modularity" and "silhouette" metrics (Gaggero et al., 2020) (Tables 3 and 4).

There are several softwares or applications to map knowledge domains, such as CiteSpace, VOSviewer, BibExcel, etc. We decided to use CiteSpace, not only because of the power analysis but also because it is configured according to each researcher's needs, and, thus this makes it the best tool for working with bibliographic information, including Web of Science and Scopus databases (Zhang et al., 2020; Zhai et al., 2021; Amini et al., 2021). CiteSpace processes data into network patterns and helps identify thriving topical areas and novel research patterns[1] by decomposing the network into clusters supported by temporal analyses. It succors collaboration networks, author co-citation networks, and document co-citation networks investigations. The networks developed in CiteSpace consist of nodes that represent the types of entities (e.g., authors, journals, and references) and links that represent the relationship between the nodes (Zhai et al., 2021).

Data Collection

Data was collected from the Web of Science Core Collection, which is the premier resource on the Web of Science and the world's most trusted citation index for scientific and scholarly research. This collection is comprised of 21,000 peer-revied journals published worldwide in over 250 disciplines.[2] Based on the research framework and review studies, such as (Daheim, Uerz, 2008; Rohrbeck et al., 2015; Gordon et al., 2020), the following query was built and searched on WoS: *Query* = ("Corporate foresight" OR "Strategic foresight" OR "Organizational foresight"). The period was set to 2000 to 2021. From this query, the initial result was 435 publications. Since there

Table 3. **Cluster Metrics for Detecting the Overall Structure of the Networks**

Metrics	Description
Modularity Q	Regarding the modularity Q of a network, it is the degree to which it can be split into inde-pendent blocks. The modularity score ranges between 0 and 1 (Chen et al. (2010). A net-work with low modularity, closest to 0, cannot be reduced to clusters with defined bounda-ries, whereas a network with high modularity may be well structured, meaning that it can be divided into clear clusters. However, the closer to 1, the more a cluster will be isolated, dis-persing the network (Chen et al., 2010).
Silhouette	The silhouette metric can be used to estimate the uncertainty in determining the nature of a cluster (Rousseeuw, 1987). The silhouette value, which ranges from -1 to 1, shows the de-gree of uncertainty that must be considered when understanding the nature of the cluster. A value of 1 denotes the complete isolation from other clusters, which represents an easier way to label the clusters (Chen et al., 2010).

Source: authors.

[1] http://cluster.cis.drexel.edu/%7Ecchen/CiteSpace/, accessed 10.08.2021.

[2] https://clarivate.libguides.com/webofscienceplatform/woscc, accessed 02.08.2021.

Table 4. **Node Selection Criteria**

Metrics	Description
G-Index	The g-index is the (unique) greatest number (in which articles are ordered in decreasing order of the number of citations they received) such that the top g articles got (collectively) at least g2 citations (Egghe, 2006). The number of citations in an author's most important articles is factored into the g-index. The highest number that equals the average number of citations of the most highly referenced g publications is the g-index. CiteSpace employs a modified g-index with a scaling factor k to make it even more versatile. The k parameter can be any positive value, allowing the user to tailor the total size of the resulting network to their requirements.*
Top N	This criterion selects the N articles that were most cited and utilizes data from them to build the network for each time slice (Gaggero et al., 2020).
Top N%	This criterion selects the N% articles that were most cited and utilizes data from them to build the network for each time slice (Gaggero et al., 2020).

* https://sites.google.com/site/CiteSpace101/6-configure-a-CiteSpace-run/6-4-node-selection, accessed 10.09.2021.

Source: authors.

are zero papers from 2000, the final timespan was set, 2001-2021. This timeframe was selected because it allows for a deep interpretation of the past two decades of the research stream.

In order to improve the effectiveness of data processing, analyzing, and interpreting, the data was preliminarily filtered using the principal criteria that all papers must have a title and abstract in English. No language barrier was implemented. It was decided that all publications, English, Russian, German, French, Spanish, and Portuguese publications should not be excluded from the analysis, because CiteSpace has the computational power to analyze different languages. However, poetry and letters were filtered out leaving only 433 results (346 articles, 65 proceeding papers, 19 review articles, 13 editorial materials, eight early access papers, and six book reviews).

Data Processing

A descriptive analysis of publication frequency over time and a descriptive analysis of citation frequency over time allowed for understanding how CF evolved over the past few decades. We conducted a descriptive analysis, based on WoS data of the top 10 journals according to publications and citations, followed by the top 10 authors per publications and citations, the top 40 most used keywords (author keywords and keywords plus[3]), and finally the top 10 most cited publications to have an overview of the sample's data. These descriptive analyses allowed us to understand how the CF domain is structured.

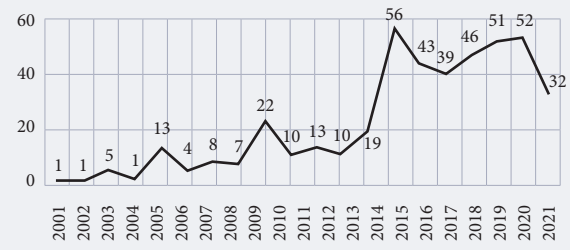
Networks of publications, authors, keywords, and publications were visualized and evaluated using the metrics: frequency, degree of centrality, betweenness, burst value, and sigma value. To continue to understand what the current trends on CF are, we did a clustering analysis on the publications, using the labeling method LLR (Log-Likelihood Ratio). Considering that we wanted to focus our attention on the current trends, we selected the clusters that had recent activity, meaning the ones that had publications in 2020 or 2021. After selecting the clusters, we then focused our attention on the publications that had burst periods covering 2021. It should be noted that for the descriptives and bibliometrics no difference was made between journals, conference proceedings, or scientific books.

Results

Descriptive Analysis

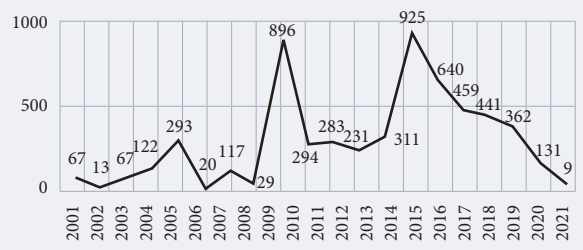
This section presents some descriptive analyses: the publication frequency and citation frequency of CF

Figure 1. **Query Publication Frequency**



Source: authors.

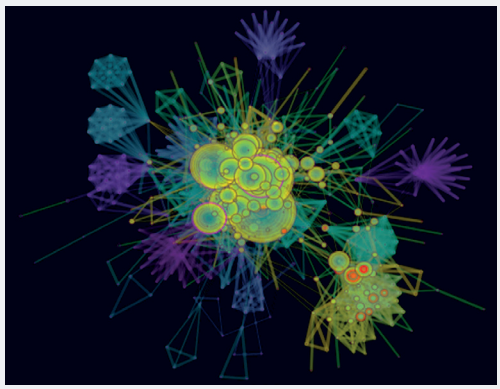
Figure 2. **Query Citation Frequency**



Source: authors.

[3] Keywords plus are words or phrases that frequently appear in the titles of an article's references, but do not appear in the title of the article itself. Based upon a special algorithm that is unique to Clarivate databases, KeyWords Plus enhances the power of cited reference searching by searching across disciplines for all the articles that have cited references in common. https://support.clarivate.com/ScientificandAcademicResearch/s/article/KeyWords-Plus-generation-creation-and-changes?language=en_US, accessed 02.08.2021

Figure 3. **Journal Co-citation Network**



Source: authors.

literature, followed by a journal, authors, keywords, and document analysis.

In relation to *publication frequency*, Figure 1 shows that, since 2001, the number of publications, regarding corporate foresight has gradually increased and 85.68% of the publications were published after 2010. Furthermore, it is possible to see that, in 2001, there was only one publication and, in 2015, the number of publications reached a peak of 56.

Figure 2 presents the number of citations per year (*citation frequency*) for all the 433 articles that composed the data between 2001 and 2021. In total 5,670 citations occurred during the studied period. It is possible to identify two citation peaks: one in 2010, with 896 citations, and another in 2015, with 925 citations. Moreover, 71.26% of the citations occurred after 2010. In contrast, it is possible to observe that the overall citation frequency has been decreasing since 2015.

As to *journal co-citation,* the 433 papers were published in 191 different journals and 154 of those journals only published one paper. In contrast, the 10 journals with more publications accounted for 50.5% of the total publications, see Table 5.

Table 6 shows the top 10 journals based on their citation count. As we see, these 10 journals accumulated 5,670 total citations. The top 10 journals with more citations accounted for 72.61% of the total.

The 433 studies used on the dataset were published by 1,043 distinct authors. In the following table, Table 7, in the column Acc % of 433, we can see that 41.8% (181 publications) of the 433 published papers were produced by 32 authors.

In Table 8, it is possible to see the most cited authors from a total of 38,350 co-citations. René Rohrbeck is in first place with 674 citations from the 17 papers that he participated in, followed by Senthold Asseng with 441 citations, Gerrit Hoogenboom, and Joost Wolf with 389 citations each, and so on. In total, the top 10 most cited authors represent 10.65% of the total number of co-citations.

The following table, Table 9, describing *Co-occurring Author Keywords* shows the top 20 most used keywords (author keywords and keywords plus) from a total of 1,813 distinct keywords. It is possible to see that the 10 most used keywords account almost for 20% of the total keywords used in all papers from our dataset and the top 20 most used keywords account for 26.31% of the total keyword utilization.

Finally, regarding *Document Co-citation,* Table 10 presents the most cited papers from a total of 5,670 ci-

Table 5. **Publications per Journal (2001–2021)**

Journal Name	Number of Publications	Share of 433 (%)	Acc. % of 433*
Technology Forecasting and Social Change	78	18.01	18.01
Futures	50	11.55	29.56
Foresight	28	6.47	36.03
Technology Analysis & Strategic Management	15	3.46	39.49
European Journal of Futures Research	13	3.00	42.49
Journal of Futures Studies	8	1.85	44.34
Global food Security	7	1.62	45.96
Foresight and STI Governance	7	1.62	47.58
Technology Innovation Management Review	7	1.62	49.19
Futurist	6	1.39	50.58
TOTAL	433		

Editorial note: * * In this and subsequent tables, the value of Acc. % means the sum of the individual shares of the current and higher ranking positions in the total sample.

Source: authors.

Table 6. **Citations per Journal (2001–2021)**

Journal Name	Citation Count	Share of 5670 (%)	Acc. % of 5670
Technological Forecasting and Social Change	2216	39.08	39.08
Futures	766	13.51	52.59
Nature Climate Change	296	5.22	57.81
Technology Analysis & Strategic Management	201	3.54	61.36
Global Change Biology	144	2.54	63.90
Foresight	123	2.17	66.07
Marketing Science	122	2.15	68.22
Global Food Security	89	1.57	69.79
Conservation Letters	82	1.45	71.23
R&D Management	78	1.38	72.61
TOTAL	5670		

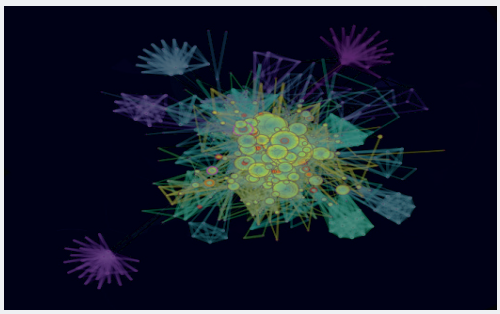
Source: authors.

Table 7. **Publications per Author (2001–2021)**

Rank	Author Name	Number of Publications	Share of 433 (%)	Acc. % of 433
1	René Rohrbeck	17	3.93	3.93
2	David Sarpong	12	2.77	6.70
3	Daniel Mason-d'croz	10	2.31	9.01
4	Dirk Meissner	10	2.31	11.32
5	Konstantin Vishnevskiy	9	2.08	13.39
6	Melanie Wiener	8	1.85	15.24
7	Riccardo Vecchiato	7	1.62	16.86
8	Senthold Asseng	6	1.39	18.24
9	Sika Gbegbelegbe, Jari Kaivo-Oja, Anna Kononiuk, Pierre Martre, Richard D. Robertson, Heiko A.von der Gracht	5	1.15 each (6.93 total)	25.17
10	Cinzia Battistella, Frank Ewert, Regina Gattringer, Guy Hareau, Gerritt Hoogenboom, Oleg Karasev, Kurt-Christian Kersebaum, Mairi Maclean, Matthew P. Reynolds, Sherman Robinson, Alex Ruane, Jan Oliver Schwarz, Mikhail Semenov, William J. Sutherland, Victor Tiberius, Julia Rose West, Keith Wiebe, Joost Wolf	4	0.92 each (16.63 total)	41.80

Source: authors.

Figure 4. **Author Co-Citation Network**



Source: authors.

Table 8. **Citations per Author for the Top 10 Authors (2001–2021)**

Rank	Author Name	Number of Citations	Share of 38360 (%)	Acc. % of 38360
1	René Rohrbeck	674	1.76	1.76
2	Senthold Asseng	441	1.15	2.91
3	Gerritt Hoogenboom	389	1.01	3.92
4	Joost Wolf	389	1.01	4.93
5	Davide Cammarano	372	0.97	5.90
6	Frank Ewert	364	0.95	6.85
7	Kurt-Christian Kersebaum	364	0.95	7.80
8	Pierre Martre	364	0.95	8.75
9	Ehsan Eyshi Rezaei	364	0.95	9.70
10	Mikhail Semenov	364	0.95	10.65

Source: authors.

tations in the 433 papers. The top 10 most cited publications account for 20.48% of the total citations.

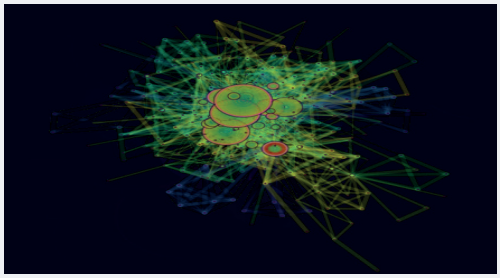
Bibliometric Analysis

In this section, we will present the results of our bibliometric analysis for the document, author, journal, and keyword co-citation network. In Figures 3–6 it is possible to see that items with more citations as they are represented by a larger circle. The circle with a purple ring represents the journals with a betweenness centrality higher than 0.1, and the thicker the ring, the higher the centrality (Chen, 2010). Additionally, the circles with a red ring indicate a burst item (Chen, 2010). For example, the journal network (Figure 3) contains 589 nodes and 3,432 links. In Table 11, is possible to see the top 20 cited journals with the strongest citation burst from a total of 39 automatically generated bursts using CiteSpace.

Table 12 represents the top 10 journals by metric (frequency, burst, degree, centrality, and sigma). We can see that the journal of *Technology Forecasting and Social Change* was cited 237 times. Moreover, the *Journal of Cleaner Production* has the highest burst value, 5.68. The journal *Administrative Science Quarterly* has the biggest degree of centrality (102) and the higher betweenness centrality value (0.2). *Global Environment Change* has the highest sigma, 1.32.

Figure 4 represents a visualization of the author's co-citation network. This network contains 594 nodes and 3,558 links. In Figure 4 it is possible to see the authors with more citations as they are represented with a larger circle, the authors with higher betweenness centrality, and the ones that are considered burst items. Table 13 shows the top 20 cited authors with the strongest citation bursts and time of burst.

Figure 5. **Co-Occurring Author Keywords Network**



Source: authors.

Table 14 shows the top 10 authors from the author co-citation network per metric. From Table 14 we can see that René Rorhbeck was the most cited author, 146 times, Harry Igor Ansoff has the highest degree of centrality, 79, and Michael Porter has the highest betweenness centrality value, 0.15. Harry Igor Ansoff has the highest burst value, 7.26, and he also had the highest sigma value, 2.12.

Figure 5 represents a visualization of the co-occurring author keywords network. This network contains 312 nodes and 1,656 links. In Figure 5 it is possible to see the most used keywords as they are represented with a larger circle, the keywords with higher betweenness, centrality and, although more difficult, the ones that are considered burst items. Table 15 shows the top five keywords with the strongest citation burst and time of occurrence.

In Table 16 it is possible to see the top 10 keywords by metric. The keyword "Future" was the most used keyword, 88 times, "Management" had the highest degree of centrality and betweenness centrality, 81 and 0.19, respectively, and "Perception" had the highest burst value, 2.95, and "Impact" held the highest sigma value, 1.50.

Figure 6 represents a visualization of the document co-citation network. This network contains 663 nodes and 2,315 links. In Figure 6 it is possible to see the most cited references as they are represented with a larger circle and the ones that are considered burst items. Zero references had a betweenness centrality higher than 0.1 and therefore in the network, no purple ring can be identified. Table 17 shows the top 20 references with the strongest citation burst.

Table 18 shows the top 10 references per metric. From Table 18 we can see that the reference (Rohrbeck et al., 2015) was the most cited, 47 times, (Heger, Boman, 2015) had the highest degree of centrality, 37, and (Rohrbeck, Kum, 2018) had the greatest betweenness centrality, 0.07. Furthermore, (Rohrbeck et al., 2015) had the highest burst value, 13.82, and (Rohrbeck, Kum, 2018) had the highest sigma value, 1.90.

Table 9. **Number of Used Keywords (2001–2021)**

Rank	Keywords	Frequency [2001-2021]	Share of 3861 (%)	Acc. % of 3861
1	Strategic Foresight	165	4.27	4.27
2	Corporate Foresight	145	3.76	8.03
3	Innovation	95	2.46	10.49
4	Foresight	67	1.74	12.22
5	Future	67	1.74	13.96
6	Management	49	1.27	15.23
7	Technology	49	1.27	16.50
8	Scenarios	40	1.04	17.53
9	Performance	38	0.98	18.52
10	Futures	37	0.96	19.48
11	Decision Making	34	0.88	20.36
12	Impact	33	0.85	21.21
13	Uncertainty	30	0.78	21.99
14	Knowledge	27	0.70	22.69
15	Dynamic Capabilities	26	0.67	23.36
16	Strategy	25	0.65	24.01
17	Technology Foresight	23	0.60	24.61
18	Climate Change	22	0.57	25.17
19	Framework	22	0.57	25.74
20	Organizations	22	0.57	26.31

Source: authors.

Table 10. **Citations per Reference (2001–2021)**

Rank	Publications	Number of citations	Number of 5670	Acc. of 5670
1	(Liu et al., 2016)	198	3.49	3.49
2	(Rohrbeck, Gemünden, 2011)	155	2.73	6.23
3	(Durance, Godet, 2010)	124	2.19	8.41
4	(Naik et al., 2005)	122	2.15	10.56
5	(Asseng et al., 2019)	105	1.85	12.42
6	(Springmann et al., 2017)	98	1.73	14.14
7	(Rohrbeck, Schwarz, 2013)	91	1.60	15.75
8	(Rohrbeck et al., 2015)	90	1.59	17.34
9	(Vecchiato, Roveda, 2010)	90	1.59	18.92
10	(Habegger, 2010)	88	1.55	20.48

Source: authors.

Table 11. **Top 20 Cited Journals and Books with the Strongest Citation Bursts (2001–2021)**

Cited Journals (Books)	Strength	Begin	End	2001–2021
Social Psychology Network*	3.61	2004	2010	
Competing for the Future (Hamel, Prahalad, 1994)	3.18	2004	2011	
American Journal of Sociology	3.31	2006	2015	
The Art of the Long View (Schwartz, 1996)	4.45	2008	2012	
Competitive Advantage (Porter, 2008)	3.63	2010	2012	
Futures Research Methodology (Glenn, Gordon, 2009)	3.79	2012	2014	
Peripheral Vision (Day, Schoemaker, 2006)	3.39	2012	2015	
Handbook of Research Methodology (Mishra, Alok, 2017)	3.35	2013	2015	
Strategic Change	3.34	2015	2016	
PNAS	3.72	2016	2017	
Nature Journal	4.05	2016	2018	
Psychological Review	3.17	2016	2018	
Global Environmental Change	3.86	2016	2019	
Environment Research Letters	4.42	2016	2019	
European Journal of Agronomy	3.59	2016	2019	
Nature Climate Change	3.59	2016	2019	
Global Change Biology	3.31	2016	2019	
International Journal of Management Reviews	3.78	2018	2021	
Journal of Cleaner Production	5.68	2019	2021	
Journal of Applied Psychology	3.52	2019	2021	

* https://www.socialpsychology.org/, accessed 12.02.2022.
Source: authors.

As to the document co-citation clustering analysis, CiteSpace grouped the references into 82 clusters, which resulted in a mean modularity Q of 0.8214 and a mean silhouette value of 0.9157. CiteSpace only displays the largest connected component of the network by default, as a result, clusters that are not part of the biggest linked component will be invisible.[4] Therefore, from the 82 clusters, CiteSpace only displays nine clusters. In the following table, Table 19, it is possible to see the nine clusters' information and in Figure 7, the timeline view of the clusters and the respective interconnections between the references of each cluster.

Figure 6. **Document Co-Citation Network**

Source: authors.

To answer our research problem, using all the references with a burst value greater than zero, arranged by cluster, we focused our attention on the references that have a burst period covering 2021, as those that might indicate the current trends and hot topics surrounding corporate foresight (see Table 20) and, to have a better understanding of the references' characteristics, we also obtained the results of centrality and newness associated with the selected references.

As shown in Table 20, the references with a burst period covering 2021 belong to one of two clusters: cluster 0 (named "Open Foresight") and cluster 2 (named "Research Opportunities"). The name of the cluster is given by the LLR (log-likelihood ratio) algorithm.

Discussion

The descriptive analyses concerning publication frequency and citation frequency over the period 2001–2021 sought to acknowledge the evolution of CF research over the last two decades. Our results showed that there is visual parallelism between the two evolutionary lines (see Figures 1 and 2) from 2001 to 2017. We noticed that more than 85% of the total publications and more than 70% of the citations occurred after 2010, both reaching a peak in 2015, which means that interest in CF was higher after 2010. This might be related to the fact that in 2010 the world was still facing the effects of 2008 economic crisis and resulting periods of uncertainty. Furthermore, CF is a key instrument for battling uncertainty that has emerged as an important contributor in the face of accelerating change, high business environment unpredict-

[4] https://CiteSpace.podia.com/faq, accessed 09.09.2021.

Table 12. **Top 10 Journals per Bibliometrics (2001–2021)**

Rank	Journal (Book)	Value
	Frequency	
1	*Technological Forecasting & Social Change*	237
2	*Futures*	215
3	*Foresight*	155
4	*Technology Analysis and Strategic Management*	127
5	*Strategic Management Journal*	126
6	*Long Range Planning*	116
7	*Harvard Business Review*	114
8	*Academy of Management Review*	111
9	*Organization Science*	88
10	*Administrative Science Quarterly*	83
	Burst	
1	*Journal of Cleaner Production*	5.68
2	The Art of the Long View	4.45
3	*Environmental Research Letters*	4.42
4	*Nature*	4.05
5	*Global Environmental Change*	3.86
6	*Futures Research Methodology*	3.79
7	*International Journal of Management Reviews*	3.78
8	*PNAS*	3.72
9	Competitive Advantage	3.63
10	Social Psychology Network	3.61
	Degree	
1	*Administrative Science Quarterly*	102
2	*Academy of Management journal*	101
3	*Long Range Planning*	74
4	*Academy of Management Review*	74
5	*Strategic Management Journal*	65
6	*California Management Review*	65
7	*Journal of Management*	63
8	*Organization Science*	58
9	*Journal of Management Studies*	58
10	*Harvard Business Review*	55
	Centrality	
1	*Administrative Science Quarterly*	0.20
2	*Academy of Management journal*	0.17
3	*Harvard Business Review*	0.11
4	*Futures*	0.09
5	*Science*	0.09
6	The Art of Conjecture (De Jouvenel, 2012)	0.09
7	*Journal of Future Studies*	0.08
8	*California Management Review*	0.07
9	The Art of the Long View	0.07
10	*American Economic Review*	0.07
	Sigma	
1	The Art of the Long View	1.33
2	*Global Environment Change*	1.32
3	Handbook of Research Methodology	1.28
4	*PNAS*	1.11
5	Competing for the Future	1.07
6	*Strategic Change*	1.05
7	Futures Research Methodology	1.04
8	*Journal of Cleaner Production*	1.03
9	*Environmental Research Letters*	1.03
10	*International Journal of Management Reviews*	1.03

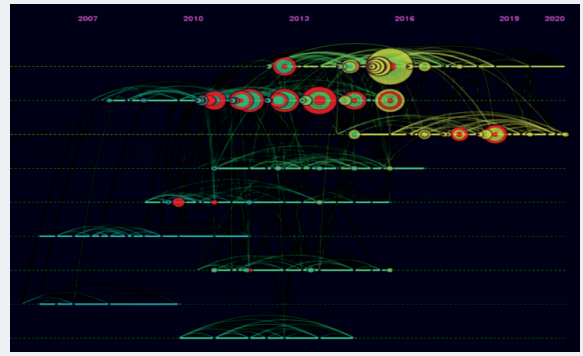
Source: authors.

Table 13. **Top 20 Cited Authors with the Strongest Citation Bursts (2001–2021)**

Cited Authors	Strength	Begin	End	2001–2021
Harry Igor Ansoff	7.26	2006	2012	
Peter Schwartz	4.27	2006	2012	
Liam Fahey	3.91	2006	2015	
Alan Porter	4.30	2010	2012	
Darrell Rigby	3.66	2012	2015	
Tobias Gnatz	3.55	2013	2015	
Effie Amanatidou	5.21	2014	2016	
Heiko von der Gracht	3.95	2014	2015	
Theodore Gordon	3.82	2014	2015	
Averil Horton	4.44	2016	2018	
Konstantin Vishnevskiy	3.91	2016	2019	
Frank Ruff	4.95	2017	2018	
Patrick van der Duin	4.59	2017	2021	
Angela Wilkinson	3.62	2017	2021	
Martin Rhisiart	3.94	2018	2021	
Siri Boe-Lillegraven	3.87	2018	2021	
Jakob Højland	3.61	2018	2021	
Regina Gattringer	3.61	2018	2021	
Jon Iden	6.25	2019	2021	
Tugrul Daim	3.70	2019	2021	

Source: authors.

Figure 7. **Clusters Timeline View**



Cluster 0 — Open Foresight
Cluster 1 — Rich Tradition
Cluster 2 — Research Opportunities
Cluster 3 — Accelerating Technological Change
Cluster 4 — Way Finding
Cluster 7 — Proposal
Cluster 8 — Assessing Delphi Panel Composition
Cluster 12 — Portfolio Approach
Cluster 13 — Conservation Opportunity

Source: authors.

Table 14. **Top 10 Authors by Bibliometrics (2001–2021)**

Rank	Author	Value
	Frequency	
1	René Rohrbeck	146
2	Ricciardo Vecchiato	96
3	Cornelia Daheim	63
4	Kathleen Eisenhardt	59
5	Frank Ruff	51
6	Tobias Heger	50
7	Michel Godet	49
8	Peter Schwartz	48
9	Kees van der Heijden	48
10	Andy Hines	48
	Burst	
1	Harry Igor Ansoff	7.26
2	Jon Iden	6.25
3	Effie Amanatidou	5.21
4	Frank Ruff	4.95
5	Patrick van der Duin	4.59
6	Averil Horton	4.44
7	Alan Porter	4.30
8	Peter Schwartz	4.27
9	Heiko von der Gracht	3.95
10	Martin Rhisiart	3.94
	Degree	
1	Harry Igor Ansoff	79
2	George Burt	63
3	Cornelia Daheim	62
4	Kathleen Eisenhardt	57
5	René Rohrbeck	55
6	Thomas Chermack	55
7	Gary Hamel	53
8	Joseph Coates	53
9	Paul Schoemaker	50
10	Tobias Heger	48
	Centrality	
1	Michael Porter	0.15
2	Harry Igor Ansoff	0.11
3	George Day	0.10
4	Gary Hamel	0.08
5	Richard Daft	0.07
6	Sohail Inayatullah	0.07
7	David Teece	0.07
8	George Burt	0.06
9	Kathleen Eisenhardt	0.06
10	Michel Godet	0.06
	Sigma	
1	Harry Igor Ansoff	2.12
2	Effie Amanatidou	1.22
3	Michel Godet	1.19
4	Heiko von der Gracht	1.11
5	Rafael Ramirez	1.09
6	Frank Ruff	1.08
7	Liam Fahey	1.08
8	Alper Alsan	1.08
9	Alan Porter	1.08
10	Averil Horton	1.07

Source: authors.

Table 15. **Top 5 Keywords with the Strongest Citation Bursts (2001–2021)**

Keywords	Strength	Begin	End	2001–2021
Perception	2.95	2006	2012	
Real Time	2.68	2013	2015	
Industry	2.27	2017	2018	
Open Innovation	2.57	2018	2019	
Impact	2.32	2019	2019	

Source: authors.

ability, and an unprecedented volume of information. Furthermore, we saw that, after 2017, both evolutionary lines (publication frequency and citation frequency) diverged until 2021: the publication frequency increased, suggesting that there was a rising interest in CF in that period, and the citation frequency declined, suggesting that the most cited articles are not the most recent publications. Overall, the increased number of publications and citations, over the past few decades, suggests that CF is evolving from a new knowledge frontier into a well-established one and that this is in line with findings by (Amini et al., 2021).

The results of descriptive analyses on the journals, authors, keywords, and documents showed that the 433 studies were published in 191 journals, which demonstrates some diversity and interest, and that, 50.5% of those studies were published only in 10 journals, which suggests that those 10 journals are more interested in corporate foresight literature (see Table 5). Moreover, the first two journals that published more articles related to CF, the *Technological Forecasting and Social Change* and *Futures* journals are also the two journals that received more citations probably because the names of the journals are associated with the relationship between CF and uncertainty motivated by the social and economic development due to the rapid technological changes and the rapid diffusion of innovations (Latzer, 2009) and also because CF is seen as a future-oriented strategy (Vecchiato, 2015). Furthermore, four of the top 10 most cited journals are natural sciences journals: *Nature Climate Change*, *Global Change Biology*, *Conservation Letters,* and *Global Food Security-Agriculture Policy Economics and Environment* (see Table 6). This might suggest an increasing interest in foresight studies by natural sciences practitioners. Additionally, finding general management journals in these top 10 most cited journals, such as *Technology Analysis & Strategic Management* and *Technology Innovation Management Review* and *Marketing Science* and *R&D Management*, might also suggest an increasing interest from the general strategic management school in CF.

Looking into the authors' descriptive analysis, we can see that more than 41% of the 433 publications (181 publications) were developed by 32 authors,

Table 16. **Top 10 Keywords by Metric (2001–2021)**

Rank	Keyword	Value
	Frequency	
1	Future	88
2	Corporate Foresight	86
3	Innovation	67
4	Strategic Foresight	56
5	Technology	47
6	Management	43
7	Impact	38
8	Performance	38
9	Knowledge	26
10	Uncertainty	24
	Burst	
1	Perception	2.95
2	Real Time	2.68
3	Open Innovation	2.57
4	Impact	2.32
5	Industry	2.27
6	Future	–
7	Corporate Foresight	–
8	Innovation	–
9	Strategic Foresight	–
10	Technology	–
	Degree	
1	Management	81
2	Innovation	72
3	Corporate Foresight	71
4	Performance	68
5	Future	65
6	Impact	62
7	Decision Making	62
8	Knowledge	58
9	Strategic Foresight	54
10	Framework	53
	Centrality	
1	Management	0.19
2	Impact	0.19
3	Performance	0.15
4	Innovation	0.13
5	Corporate Foresight	0.13
6	Future	0.13
7	Decision Making	0.10
8	Strategic Foresight	0.10
9	Framework	0.10
10	Uncertainty	0.10
	Sigma	
1	Impact	1.50
2	Industry	1.14
3	Perception	1.11
4	Real Time	1.02
5	Management	1.00
6	Performance	1.00
7	Innovation	1.00
8	Corporate Foresight	1.00
9	Future	1.00
10	Decision Making	1.00

Source: authors.

Table 17. **Top 20 References with the Strongest Citation Bursts (2001–2021)**

References	Strength	Begin	End	2001–2021
(Vecchiato, Roveda, 2010)	7.36	2012	2015	
(Rohrbeck, Gemunden, 2011)	10.57	2013	2016	
(Von der Gracht et al., 2010)	6.12	2013	2015	
(Bootz, 2010)	4.06	2013	2015	
(Rohrbeck, 2012)	7.42	2014	2017	
(Heger, Rohrbeck, 2012)	6.79	2014	2017	
(Vecchiato, 2012)	6.54	2014	2016	
(Rohrbeck, 2011)	5.92	2014	2016	
(Rohrbeck, Schwarz, 2013)	8.73	2015	2018	
(Battistella, 2014)	4.30	2015	2018	
(Vishnevskiy et al., 2015)	3.71	2016	2019	
(Ruff, 2015)	6.40	2017	2019	
(Van der Duin et al., 2014)	4.83	2017	2019	
(Rohrbeck et al., 2015)	13.82	2017	2021	
(Heger, Boman, 2015)	4.87	2017	2021	
(Boe-Lillegraven, Monterde, 2015)	4.29	2017	2021	
(Vecchiato, 2015)	3.76	2017	2021	
(Paliokaitė, Pačėsa, 2015)	3.71	2017	2021	
(Rohrbeck, Kum, 2018)	8.97	2019	2021	
(Iden et al., 2017)	6.20	2019	2021	

Source: authors.

which indicates that those authors are strongly interested in the proliferation of the CF approach. Authors such as René Rohrbeck, Dirk Meissner, Konstantin Vishnevskiy, Ricciardo Vecchiato, David Sarpong, and Melanie Wiener, among others, focus their efforts on research related to corporate foresight, strategic foresight, futures, scenarios, and open foresight and its impacts on management, innovation, and technology. Moreover, authors such as David Mason-d'Croz, Senthold Asseng, and others focus their efforts on future perspectives and scenarios research linked to agricultural and climate issues. Therefore, it might suggest, once again, the increased interest in foresight studies in the natural science area. The same applies to the most cited authors, who, besides René Rohrbeck, all have publications concerning climate change because most of them worked together on those publications.

Regarding the keywords' descriptive analysis, we can see that from the 1,813 distinct references used in all 433 documents, the top 40 keywords were used 33% of the time. As expected, the two most used keywords are "strategic foresight" and "corporate foresight". Moreover, when looking into the remaining keywords, we can see the connection between CF and innovation, technology, scenarios, performance,

Table 18. **Top 10 Reference by Bibliometrics (2001–2021)**

Rank	Publication	Value
	Frequency	
1	(Rohrbeck et al., 2015)	88
2	(Rohrbeck, Schwarz, 2013)	86
3	(Rohrbeck, Gemünden, 2011)	67
4	(Rohrbeck, 2012)	56
5	(Heger, Rohrbeck, 2012)	47
6	(Ruff, 2015)	43
7	(Vishnevskiy et al., 2015)	38
8	(Rohrbeck, Kum, 2018)	38
9	(Vecchiato, Roveda, 2010)	26
10	(Rohrbeck, 2011)	24
	Burst	
1	(Rohrbeck et al., 2015)	13.82
2	(Rohrbeck, Gemünden, 2011)	10.57
3	(Rohrbeck, Kum, 2018)	8.97
4	(Rohrbeck, 2012)	8.73
5	(Vecchiato, Roveda, 2010)	7.42
6	(Rohrbeck, 2011)	7.36
7	(Heger, Rohrbeck, 2012)	6.79
8	(Vecchiato, 2010)	6.54
9	(Ruff, 2015)	6.4
10	(Iden et al., 2017)	6.2
	Degree	
1	(Heger, Boman, 2015)	37
2	(Vecchiato, Roveda, 2010)	35
3	(Vecchiato, 2015)	31
4	(Andersen, Andersen, 2014)	31
5	(Rohrbeck, Kum, 2018)	30
6	(Battistella, De Toni, 2011)	30
7	(Rohrbeck, 2011)	27
8	(Van der Duin et al., 2014)	27
9	(Paliokaite, Pačesa, 2015)	26
10	(Heger, Rohrbeck, 2012)	25
	Centrality	
1	(Rohrbeck, Kum, 2018)	0.07
2	(Vecchiato, 2015)	0.06
3	(Georghiou et al., 2009)	0.06
4	(Habegger, 2010)	0.06
5	(Vecchiato, Roveda, 2010)	0.05
6	(Andersen, Andersen, 2014)	0.05
7	(Battistella, De Toni, 2011)	0.05
8	(Daheim, Uerz, 2008)	0.05
9	(Heger, Boman, 2015)	0.04
10	(Amanatidou et al., 2012)	0.04
	Sigma	
1	(Rohrbeck, Kum, 2018)	1.90
2	(Vecchiato, Roveda, 2010)	1.48
3	(Rohrbeck et al., 2015)	1.29
4	(Rohrbeck, Gemünden, 2011)	1.28
5	(Heger, Rohrbeck, 2012)	1.25
6	(Vecchiato, 2015)	1.24
7	(Vecchiato, 2010)	1.24
8	(Heger, Boman, 2015)	1.22
9	(Vecchiato, Roveda, 2010)	1.21
10	(Battistella, De Toni, 2011)	1.18

Source: authors.

Table 19. **Document Co-Citation Clustering Information**

Cluster ID	Cluster name LLR	Size	Silhouette	From – To
0	Open Foresight	72	0.905	2012–2020
1	Rich Tradition	64	0.861	2007–2015
2	Research Opportunities	61	0.934	2014–2020
3	Accelerating Technological Change	36	0.852	2010–2016
4	Way Finding	31	0.938	2008–2015
7	Proposal	28	0.957	2010–2015
8	Assessing Delphi Panel Composition	28	0.968	2005–2011
12	Portfolio Approach	15	0.988	2005–2009
13	Conservation Opportunity	13	0.999	2009–2014

Source: authors.

impact, decision making, uncertainty, and climate change.[5]

Lastly, concerning the documents' descriptive analysis we saw that five of the most cited papers were published in the journal with the highest number of publications and citations, *Technological Forecasting and Social Change*, which, once again, suggests the importance of this journal in the proliferation of CF knowledge. Correspondingly it is possible to draw parallels with innovation, scenarios, uncertainty, and technology that are most frequently met within the same journal.

Further, most of the researchers of the top 10 most cited documents are among the top 10 most productive and most cited authors, such as René Rohrbeck, Riccardo Vecchiato, Senthold Asseng, and Frank Ewert. Moreover, similarities to the previous descriptive analyses can be drawn, because three of the ten most cited articles are related to climate change issues (Liu et al., 2016; Springmann et al., 2017; Asseng et al., 2019).

To acknowledge the current research trends in CF literature, we conducted four bibliometric analyses on journals, authors, keywords, and documents, and one clustering analysis on the documents.

By conducting the journals' bibliometric analysis, we revealed the most relevant journals in CF literature. The bibliometric results show that the journals with the highest number of relationships, measured by the degree of centrality, and the ones that are closest to a center path between other nodes, measured by betweenness centrality, are those journals related to administrative and management science, namely *Admin-*

[5] Which, once again, might suggest the increasing interest by the natural sciences.

Table 20. **Cluster Recent Burst Composition**

ARTICLE			MEASURES						
Number of citations	Publication	Keywords	Burst			2001–2021	Degree of Centrality	Betweenness Centrality	Sigma of Newness
			Value	Start	End				
Cluster 0 — Open Foresight (number of publications = 72, silhouette = 0.905)									
47	(Rohrbeck et al., 2015)	Corporate Foresight, Strategic Foresight, Review, Historical Development	13.82	2017	2021		18.0	0.02	1.29
17	(Heger, Boman, 2015)	Strategic Foresight, Business Field Exploration, Innovation Management, Open Innovation	4.87	2017	2021		37.0	0.04	1.22
15	(Boe-Lillegraven, Monterde, 2015)	Corporate Foresight, Future Research, Strategic Planning, Innovation Management, Business Environment, Automotive Business	4.29	2017	2021		20.0	0.01	1.03
18	(Vecchiato, 2015)	Corporate Foresight, Networked Foresight, Innovation Networks, Collaboration for Innovation, Open Innovation, Dynamic Capabilities	3.76	2017	2021		31.0	0.06	1.24
13	(Paliokaite, Pačesa, 2015)	Organisational Foresight, Capabilities, Exploration, Exploitation, Organisational Ambidexterity	3.71	2017	2021		19.0	0.02	1.07
10	(Rhisiart et al., 2015)	Scenarios, Strategic Foresight, Learning	3.62	2018	2021		5.0	0.00	1.00
Cluster 2 — Research Opportunities (number of publications = 61, silhouette = 0.934)									
20	(Rohrbeck, Kum, 2018)	Corporate Foresight, Future Preparedness, Firm Performance, Behavioural Theory of the Firm	8.97	2019	2021		30.0	0.07	1.90
17	(Iden et al., 2017)	Strategic Foresight, Systematic Literature Review, Corporate Foresight, Technology Foresight	6.20	2019	2021		19.0	0.01	1.06
10	(Højland, Rohrbeck, 2018)	Corporate Foresight, Business Development, Cognitive Search, Experimental Search	3.62	2018	2021		12.0	0.01	1.05
9	(Gershman et al., 2016)	State-Owned Enterprises, Corporate Foresight, Technology Roadmaps, Innovation Strategies, Innovation Management	3.26	2018	2021		14.0	0.01	1.04

Source: authors.

istrative Science Quarterly, *Academy of Management Journal*, *Academy of Management Review,* and the *Harvard Business Review*. This might suggest the need for CF practitioners to justify the value of CF in comparison to the "planning school" (Battistella, De Toni, 2011). Also, by studying the burstness, we saw that the two highest burst values belong to journals related to environmental issues, the *Journal of Cleaner Production* and the *Environment Research Letters*.

Looking at Table 11, we saw that the *Journal of Cleaner Production* is a burst item, with a value of 5.68, that covers 2021, which might suggest the interest in applying foresight to production best practices to reduce environmental impacts and thus the parallelism with the descriptive analyses results. We also noticed that the *International Journal of Management Reviews* and the *Journal of Applied Psychology* are recent burst items, which might suggest the increasing interest of the general management and psychology fields in foresight. This can be explained by the relationship of CF to higher levels of innovations and performance (Rohrbeck, Kum, 2018) and its link to the role, behavior, and mental models of stakeholders (internal and external) in the path for value creation (Rohrbeck, 2012). This goes along with what was stated in the research (Rohrbeck et al., 2015), that there is some isolation of CF from general management journals and these two journals might be good solutions to break path dependency from the journals *Technological Forecasting and Social Change and Futures* that publish the most CF articles and are the most frequently cited journals. The higher burst value and recent burst period might suggest that the *Journal of Cleaner Production*, *International Journal of Management Reviews*, and *Journal of Applied Psychology* might be good journals to publish CF papers currently because they can bring more citations for a paper.

Building and analyzing the authors' bibliometric network exposed predominant authors in CF literature. Similarly to the journal centrality metrics, in both degree and betweenness, we saw that the top author is an author related to the "planning school", Harry Igor Ansoff, and, again, it might suggest the use of his work to justify the need for CF in the managerial world (Battistella, De Toni, 2011). The same applies to the burst value and sigma metrics, where the top author is Harry Igor Ansoff. This follows what is specified in the managerial world, that Ansoff is the prominent reference in strategic management (Martinet, 2010). The burst occurred between 2006-2012, which might

Table 21. **Key Findings from Cluster #0 and Cluster #2 Articles**

Article	Main findings
	Cluster 0 (Open Foresight)
(Rohrbeck et al., 2015)	• CF in networked organizations is an emerging issue. • A link exists between this article and the cluster since there is a connection between network organizations, collaborative exploration, and openness.
(Heger, Boman, 2015)	• Networked foresight creates value for companies and value is even higher for SMEs because MNEs focus more on their established foresight procedures. • Network partners predominantly see value creation from sensing activities. • The link between this article and the cluster is the aim to provide an understanding of value creation of foresight in networks.
(Boe-Lillegraven, Monterde 2015)	• A fundamental mechanism of a system like the radar is its probing of analytical thinking, as well as its means of connecting and exchanging perspectives across functions and departments. • Implications for future studies into the processes through which foresight delivers value, as well as for the practice of planning, executing, and encouraging involvement in technological foresight.
(Vecchiato, 2015)	• Acknowledgement is needed for a framework that is aware of the true value of CF and thereby the financial advantage that can be gained by incorporating CF in firms' operations. • Highlights the need to study first-mover advantages and strategies made by decision-makers as well as the conditions under which such views may be successful.
(Paliokaite, Pačesa, 2015)	• Environmental scanning, integrative and strategic selection capabilities foster radical innovations, and integrating capabilities foster incremental innovations. • Regular environmental scanning, visioning (road mapping and scorecard), R&D capacity and continuous organizational learning, strong leadership capabilities, and building future scenarios to acquire new information are key subjects for firms to invest in to increase their explorative innovation outcomes.
(Rhisiart et al., 2015)	• The learning value for individuals is domain-based (exploration and understanding of a given subject) and capacity building (know-how to use in the future). This enables collective mental models changes within the organization and enhances the sensing dynamic capabilities throughout the organization enhancing the reflection on the differences between predictive and probabilistic assumptions routinely inherent to strategists.
	Cluster 2 (Research Opportunities)
(Rohrbeck, Kum, 2018)	• Suggestion of a model for evaluating a firm's future preparedness by comparing the maturity of a firm´s CF practices and assessing the need for CF and thus validating that CF helps firms, the vigilant ones, to break path dependencies and attain higher perfor-mance and profitability. • Future prepared companies had 33% higher profitability and 200% higher market capitalization than average for the sample of studied firms.
(Iden et al., 2017)	• Increasing academic interest, but the strategic foresight field is disorganized and there is a lack of theoretical progress. • Exploratory research dominates the field. • Further explanatory research should be developed because it can also contribute to firms' success.
(Højland, Rohrbeck, 2018)	• Systematic CF methodologies are sporadically being used in the early stages, increasing the chance for opportunities to be undetected and therefore unexplored and unexploited. • Successful cases are inherent to numerous cycles of perceiving, prospecting, and prob-ing activities, implying that effective business growth, based on CF, is a non-linear process that relies on feedback loops and takes time.
(Gershman et al., 2016)	• In state-owned enterprises, there is a lack of long-term technology planning due to higher concerns with modernization, a focus on internal markets, commitment to public procurement, and the management structure.

Source: authors.

relate to the spike of CF literature in 2010. Harry Igor Ansoff is the only author with a sigma value (2.12) higher than 1.5 which is directly correlated to the influence of the author in the managerial world. CF is a new managerial subject that disrupted what the "planning school" believe regarding strategic management (see., e.g.: (Ansoff, 1988; Porter, 2008)) and the necessity to specify the limitations of their theories might suggest the appearance of Ansoff in all the metrics. Furthermore, the bibliometrics shows that Jon Iden has a burst value of 6.25 and it is a burst value that covers 2021 (see Table 13), which might suggest that some interest has been given to Jon Iden's work, for example, the systematic literature review on the nature of strategic foresight (Iden et al., 2017), because the number of citations has been increasing since 2019.

Building the keyword bibliometric network allowed us to understand research interest. From our results, we see that the keyword "management" has the highest centrality values. This might suggest that CF is a management approach that disrupts the general strategic management ("planning school") and it is a tool to fight the increasing difficulties in technology planning and innovation management as it induces companies to pursue novel innovation management mechanisms (Milshina, Vishnevskiy, 2018) as well as reassess the nature and processes of strategic decision making (Schweitzer et al., 2019).

From the results, we also noted the relationship of CF with "innovation", "impact", and "performance". This might be explained because CF is an approach that can increase future innovations and that positively impacts R&D procedures and that increases the firm performance, by anticipating environmental changes and, thus, increases value creation (Yoon et al., 2018; Hines, Gold, 2015; Rohrbeck, 2012; Rohrbeck, Gemünden, 2011; Von der Gracht et al., 2010; Adegbile et al., 2017). When looking into the burst values, we see that the most recent burst keywords

are "impact" and "open innovation". The relationship between "open innovation" and CF is based on the discussion of future strategies by involving and collaborating with internal and external stakeholders (Daheim, Uerz, 2008).

Conducting a document co-citation bibliometric analysis revealed the most important papers. Regarding the degree of centrality, the paper with more relationships with other nodes is (Heger, Boman, 2015), which studies the value of networked foresight (NF) and differentiates the benefits of NF for SMEs and multinational enterprises (MNEs). When looking into betweenness centrality, we saw that the paper with the highest betweenness centrality is (Rohrbeck, Kum, 2018), which talks about future preparedness and presents a model that analyzes future preparedness by measuring the need for CF. Regarding sigma, we saw that, once again, (Rohrbeck, Kum, 2018) has the highest value and this might suggest a higher level of novelty compared to the remaining articles. Concerning burstness, we saw that the top document that had the higher burst value (13.82) is (Rohrbeck et al., 2015), which has received more citations in the period between 2001–2021.

After that, to see connections between references, and thus highlight common topics among them, we performed a clustering analysis to the document co-citation network. From the cluster analysis, two clusters were identified as current topics, Cluster 0 and Cluster 2.

Cluster 0, labeled "Open Foresight", is the largest cluster with 72 references and has drawn interest from 2012 to 2020. "Open Foresight" refers to the most recent phase of corporate foresight as it answers to the previous challenges of CF, to the increasing complexity and dynamics of businesses, and it is based on companies shaping the future markets and contexts via a process of discussion and analysis, as mentioned by (Daheim, Uertz, 2008; Kononiuk et al., 2017; Wiener, 2018; Wiener, Boer, 2019) and others. We focused our attention on the references that are considered burst items that cover 2021. From the nine burst references, in the cluster, six of them cover 2021. The six references are summarized in Table 21.

Regarding Cluster 2, labeled "Research Opportunities", it is composed of 61 references, we focused our attention on the references that are considered a burst item that covers 2021. All four references that are considered burst items are also summarized in Table 21.

By looking into the current burst articles in Cluster 0, it is harder to draw a link to open foresight (OF) compared to CF. Nevertheless, these references might suggest that the topic of "Open Foresight" is active, since these articles can be used to justify open foresight studies. For example, it is possible to draw a parallel between network foresight, strategic agility, strong relationships with stakeholders and their involvement in the innovation process, and dynamic capabilities to open foresight. All these factors are inherent to the openness to and collaboration with other companies as studied by (Daheim, Uerz, 2008; Von der Gracht et al., 2010; Ehls et al., 2017; Kononiuk et al., 2017; Wiener, 2018; Wiener, Boer, 2019).

By looking into the current burst articles, in Cluster 2, it is possible to draw a link between the articles and the cluster labeled "Research Opportunities" since three of the four current burst articles — (Rohrbeck, Kum, 2018; Højland, Rohrbeck, 2018; Gershman et al., 2016) — are case studies and comprise exploratory research. Furthermore, the remaining article affiliation with the cluster, Iden et al. (2017) suggests that corporate foresight needs explanatory research to find answers to problems that were not studied in-depth.

To sum up, the descriptive analysis suggests that there is a tendency for the increase of future research on corporate foresight and that bibliometric analysis proposes in which journals researchers should publish their papers to obtain more citations, which authors to cite, which keywords to use, and which references to explore. This allows managers, researchers, and practitioners to gain in-depth knowledge of CF literature.

Conclusion

To our knowledge, this study was the first to study CF research, journals, authors, keywords, and documents with bibliometric analysis. The present research is based on the analysis of 433 studies published between 2001–2021 to computationally find the current trends and better understand the evolution of the field.

Our results suggest that CF research has attracted some attention in the past two decades since the publication and citation frequencies have increased. This fact is also confirmed when investigating the journals, authors, keywords, and references. Journals, such as the *Journal of Cleaner Production*, *Environmental Letters*, and *Global Environment Change* among others, from the general strategic management and natural sciences fields have started publishing foresight literature and this can be seen in both journal descriptive analysis and bibliometric analysis. The obtained results also show the influence of René Rohrbeck, Senthold Asseng, Riccardo Vecchiato, and others, with their pivotal articles in CF literature and proliferation. The results also validate the proximity relationship between CF and open innovation, industry, impacts, performance, decision-making, and uncertainty. Since those are keywords that stand out in the research by being highly used or by having high burst and sigma values. Based on centrality values, the results also suggest that CF is predominantly a management approach that disrupts the general strategic management ("planning school") and it is a tool to fight the rising difficulties in technology planning and innovation management.

The clustering analysis allowed us to understand that currently, we are in the stage, open foresight, as predicted by some authors. The combination of all the results also suggests that efforts should be given to study climate change issues while applying open foresight as a mitigation approach.

When combining both keyword bibliometric analysis (burst and sigma values) and clustering analysis, we can extrapolate the need for a continuous study of open foresight and its impact upon firm performance, as well the application of open foresight in one specific industry and the consideration of all stakeholders, internal and external, and the perceptions of this managerial approach.

Moreover, this study allowed us to acknowledge the potential of CF in both educational and practical matters. We understand the relevance of this approach for companies as a disruptive approach to the general strategic management methodology. However, we consider that efforts should be implemented to structure CF and all the subgenre topics, such as strategic foresight, organizational foresight, technological foresight, networked foresight, collaborative foresight, and open foresight. Furthermore, the results suggest that future studies should follow for an explanatory approach. This will allow one a better understanding of the field and its proliferation outside the academia.

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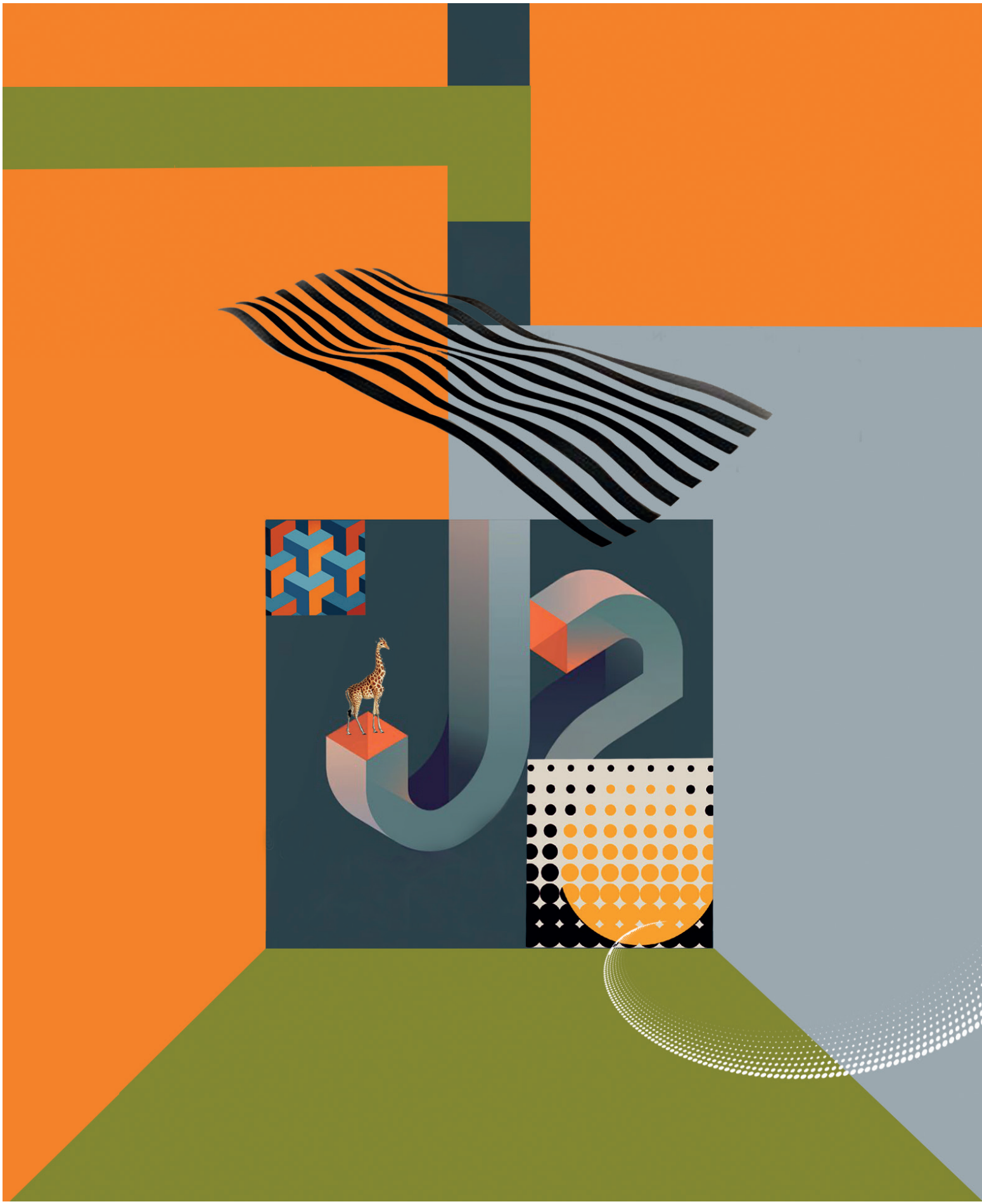

The Impact of Product and Process Innovations on Productivity: A Review of Empirical Studies

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Abstract

This article draws attention to insufficient research interest in the empirical assessments of the impact of product and process innovations (PPI) on economic performance. The analysis of the relevant studies for 2000–2022 found significant international and intersectoral differentiation of the considered linkages between innovation and productivity. It revealed limitations for the meaningful interpretation of the array of results accumulated in the literature. The author emphasizes the importance of an integrated multi-perspective approach to assessing the possible impact of PPI on various aspects of enterprise and industry performance when planning public innovation policy. For example, minor product innovations can make a tangible positive contribution to a company's sales growth, but have no impact on labor productivity at all. The impact of a radical resource-saving process innovation will look doubtful if it is evaluated only on a short time interval. The author concludes that it is expedient to revise established views on industrial technological innovations and develop new approaches to their measurement.

Keywords: product innovation; process innovation; innovation statistics; productivity

Paper type: Research Article

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Introduction

Product and process innovations (PPI)[1] directly affect productivity and other economic parameters. Process innovation reduces costs and often leads to product innovation in design and materials, while launching new products frequently requires upgrading or designing entirely new production equipment. Companies able to closely integrate PPI tend to be successful in improving their performance and launching new product lines, while the positive feedback starts a cyclical process (Reichstein, Salter, 2006; Hullova et al., 2016; Homburg et al., 2019; Ehls et al., 2020; Malek et al., 2020). According to the innovation-driven growth theory, individual PPI effects combined with the complementary impact underlie economic growth.

At the same time PPI effects and the relationship between them remain empirically understudied (Damanpour, Gopalakrishnan, 2001; Damanpour, 2010; Ballot et al., 2015; Hullova et al., 2016) and largely escape researchers' attention. A probable cause is their secondary, concomitant nature in relevant studies. Publications directly focused on innovations' complementarity tend not to consider PPI in detail. Reviews on the topic are either outdated, or not entirely relevant (Hall, 2011; Mohnen, Hall, 2013; Teplykh, 2016). Meanwhile the need to classify and structure the latest research findings on the individual and complementary impacts of PPI on productivity is becoming increasingly urgent.

This paper summarizes the results of the theoretical discussion on PPI's contribution to productivity, including measuring its elasticity. It analyzes the international and intersectoral differentiation of the relevant effects and the robustness of their econometric estimates. The role of PPI in the business cycle is discussed, along with other production factors.

Theoretical Generalizations and Hypotheses

The impact of PPI on performance can be positive or negative. A positive effect has several interpretations, equal in terms of their explanatory power. Innovations improve the efficiency of resource use, promote the application of new technologies and help weaker firms overcome the technological gap (Hall, 2011; Crespi, Zuniga, 2012). They promote the emergence of new sectors of the economy, facilitate changes in the production and specialization structure, increase the share of knowledge-intensive activities (Alvarez et al., 2015), and ultimately create sustainable competitive advantages (Hall, 2011).

A negative impact of innovation on productivity (not infrequently observed in reality) cannot be unequivocally interpreted either. It may be due to training lags (Mohnen, Hall, 2013) or disruptions in the product life cycle (Roper et al., 2008). In some cases, introducing new products interrupts the production rhythm and diverts resources from more profitable (liquid) commodity items. Innovation products may be initially produced inefficiently with negative implications for performance. Each company has a certain market power and operates in an inelastic section of the demand curve, so when process innovations improve its production efficiency, the revenue (sales) performance declines (Mohnen, Hall, 2013). Thus, the first working hypothesis can be formulated as follows:

H1: The number of statistically significant negative coefficients of PPI's impact on productivity in a representative sample of studies based on representative samples of firms will be similar for the both innovation types.

There is an opinion that less developed countries are primarily focused on gradual, minor innovations, which is why, unlike developed economies, they are mostly interested in process innovations (Cassoni, Ramada-Sarasola, 2012; Crespi, Zuniga, 2012). At the same time, the concepts of high-tech and low-tech industries' innovations are being developed in the framework of management theory (Keupp et al., 2012; Hullova et al., 2016).

High-technology industries need access to skilled labor and developed capital markets, which contributes to their (industries) being concentrated in relatively more developed countries. Product and process technologies in such sectors tend to change rapidly, which means they must be adequately synchronized with one another (Lager, Storm, 2013). Low-technology industries mainly consume and ship raw and other materials rather than finished products and components, and do not require significant amounts of expensive equipment (Frishammar et al., 2012). Innovations related to technological and business processes play a key role in their development. This is how the term "process industries" has emerged, which refers to mining, food, metal, and woodworking production. These mostly tend to be located in developing and transitional economies. Hence two other working hypotheses:

H2: PPI in high-tech industries and advanced economies make more or less the same impact on productivity and are sensitive to intangible production factors such as research and development (R&D) expenditures, patents and licenses, qualifications and skills, etc.

[1] Product innovations are defined as products (services) introduced to the market which are new or markedly improved in terms of their properties or intended uses. Such innovations imply significant improvements in technical parameters, components and materials, firmware, usability, or other functional characteristics (OECD, 2018). In their turn, process innovations are considered to be new or significantly modernized production (delivery) methods, including radical changes in techniques, equipment, and/or software (OECD, 2018). Together, PPI make up a pool of technological innovations.

H3: Process innovation plays a key role in increasing the productivity in low-tech industries and developing economies, and is sensitive to capital investment and the application of new equipment.

The phenomenon of innovations' complementarity, including PPI, deserves special consideration; studying this area goes back to Joseph Schumpeter's works (Schumpeter, 1934). Radical innovation implies not just applying PPI, but also changing the delivery system and localizing production and maintenance services. Organizations possessing valuable and rare additional assets typically tend to profit from various forms of innovation (Teece, 1986). The study (Abernathy, Utterback, 1978) is usually seen as the starting point of the complementary PPI development theory, which proposed a three-stage model of the industry life cycle. The first two stages comprise the sequential introduction of radical PPI, followed at the third phase of incremental innovations of both types. Theoreticians count up to seven types of complementarity between PPI, depending on the depth, order, and impact area (Hullova et al., 2016; Sjodin et al., 2020; Verganti et al., 2020).

Empirical studies distinguish between the two main complementarity types (Ballot et al., 2015). The first is *complementarities-in-use*, which implies that the development and application of product innovations requires introducing process innovations and vice versa. In this case the feedback between innovations of two or more types is evaluated. The second type is *complementarities-in-performance*, associated with the synergy from combining different kinds of innovations. Studying this phenomenon involves measuring the new economic value created for the company, usually in terms of productivity. The first complementarity type is not necessarily accompanied by the second. Firms may not know which combinations of innovations would work, and frequently simply imitate other players (Damanpour, 2010; Stephan et al., 2019; Pollok et al., 2019; Leo, 2020).

For the purposes of this paper, only complementarities-in-performance studies are of interest. These can be broken down into two groups: some stated assessing this effect as their main goal, while others do assess it but do not discuss in detail. The first group is less relevant to us as it generally does not focus on PPI but also covers non-technological (organizational and marketing) innovations. A common finding of such studies is that technological innovations (or all PPI) are more likely to increase firms' productivity and can do it to a greater extent when combined with non-technological ones, and vice versa. This was demonstrated on the basis of German data for in 2002-2004 (Schmidt, Rammer, 2007), British for 2002-2004 (Battisti, Stoneman, 2010), Italian for 2002-2004 (Evangelista, Vezzani, 2010), Dutch for 2000-2006 (Polder et al., 2010), Czech, Spanish, French, Italian, Portuguese, and Slovenian for 2002-2004, (Evangelista, Vezzani, 2011), Norwegian for 1999-2004 (Sapprasert, Clausen, 2012), Spanish for 2006 (Hervas-Olivier et al., 2012), and Irish for 2004-2006 (Doran, 2012).

A notable exception is the work (Ballot et al., 2015) which assessed not only PPI complementarity in the performance of British and French firms in 2002-2004, but also its differentiation by sectors of the economy, and how it was affected by various factors including non-technological innovation. The authors show that in both countries, complementarity was achieved only by small and medium-sized enterprises which did not apply any organizational innovations. It was not observed in low-tech sectors either, though in France, in the presence of organizational innovations, the PPI effects even interchanged. In high-tech sectors complementarity was only noted for British firms not engaged in organizational innovation.

Thus, PPI complementarities-in-performance turn out to be significantly differentiated geographically, which implies the need to obtain and compare detailed econometric estimates of the combined and individual impact of each of the two innovation types on productivity. Studies in the second group seem to be more useful for this purpose, with complex measurements carried out but not discussed in detail.

Based on the above, a fourth hypothesis can be suggested:

H4: On the basis of previous research, a statistically significant complementarity effect of PPI can only be positive.

Innovation is not the only productivity factor. It is customary to include qualifications, staff training costs, R&D expenditures, patenting, the use of information and communication technologies (ICT), and a number of other factors in the production function of a modern enterprise. Obviously, a significant part of them, while not being equal to innovation, are related to it, which allows us to suggest a fifth hypothesis:

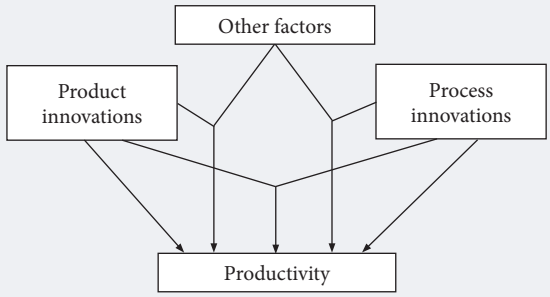
H5: The estimates of PPI's impact on productivity will be the lower with more factors included in the correlation equation.

The overall scheme of the relationship under consideration is shown in Figure 1.

Testing the Hypotheses

The variety of assessments of PPI's impact on productivity is logically due, among other things, to different ways of measuring innovation and the relationships between its effects. The best metric for output of innovative products is their cost. However, firstly, this is only applicable to product innovations, and secondly, it greatly reduces the sample of enterprises (Lööf et al., 2003; Janz et al., 2004; Criscuolo,

Figure 1. **Economic links analysed in the study**



Source: author.

2009; Wadho, Chaudhry, 2018). Binary variables (1 if the company did apply innovations of a particular type, and 0 if it did not) are less accurate (Hall, 2011), but allow one to use large samples of enterprises and estimate the complementary PPI effects on productivity (1 if the firm applied both innovation types, and 0 if not). Accordingly, in line with the stated goals and proposed hypotheses, the range of empirical studies under consideration should be limited to those using binary PPI indicators.

The search for relevant studies indexed in the academic publications databases eLibrary.ru, WoS, Scopus, ScienceDirect, JSTOR, Google Scholar, and ResearchGate for 2000-2022 revealed 26 studies published in 2004-2021. (Table 1) containing quantitative estimates of individual or combined impact of PPI on productivity. In most of them the authors did not focus on the impact under consideration, i.e., the analytical potential of their results is limited.

First of all, the possible value range of individual and complementary PPI effects is of interest. The combined effect (expressed in additional productivity gains of companies that applied both innovation types under consideration) as a rule tends to be statistically significant and have positive values (no negative values have been identified). The complementarity estimates in the studies under consideration lie in the range between 0.136 and 7.535, the individual impact of product innovations ranges between -4.148 and 3.750, and of process ones between -0.102 to 7.020. The most common interval for the three above indicators in all surveyed countries was between 0 and 1. In certain regional/industry segments, values significantly above module 1 have been recorded.

A statistically significant negative impact of product innovation was noted in two studies based on Chilean data (Alvarez et al., 2015; Santi, Santoleri, 2017). For process innovation, it was also reported in two papers based on Brazilian (Goedhuys, 2007) and Central and Eastern European (CEE) material (Hashi, Stojcic, 2013). A number of publications identified practically no differences in PPI's impact (Arvanitis, 2006; Chudnovsky et al., 2006; Griffith et al., 2006; Siedschlag et al., 2010; García-Pozo et al., 2018; Peters et al., 2018; Morris, 2018). Several papers clearly highlight the impact of either product (Musolesi, Huiban, 2010; Goedhuys, Veugelers, 2012; Acosta et al., 2015; Baumann, Kritikos, 2016) or process innovations (Vakhitova, Pavlenko, 2010; Alvarez et al., 2015; Martin, Nguyen Thi, 2015; Lin et al., 2016; Santi, Santoleri, 2017; Edeh, Acedo, 2021). In other studies, PPI's impact varies depending on the study object (sample), and econometric techniques applied (Mairesse, Robin, 2008; Masso, Vahter, 2008; Hall et al., 2009).

The high complementarity of PPI's impact was noted in several studies, for example, a study on British and French manufacturing companies in 2002-2004 (Ballot et al., 2015): the combined effect (elasticity of productivity to innovation) was estimated at 0.8-0.9. The service sector's performance in Eastern Europe, Central Asia, Latin America, and the Caribbean in 2002-2016 increased by 1.5 times (Morris, 2018). Complementarity was particularly strong (6-7.5 times) among Taiwanese original equipment manufacturers[2] in 2004-2006 (Lin et al., 2016).

Thus, the first and fourth hypotheses of our study are confirmed.

The impact of PPI on productivity, measured using the same methodology within the same time interval, significantly varies depending on the economic environment. First of all, there are discrepancies between countries. In a study of four countries' manufacturing industries in 1998-2000 (Griffith et al., 2006) a statistically significant positive impact of product innovation on productivity was found in Spain and the UK, a tangible combined effect of PPI was recorded in France, and a very small one in Germany. The spatial differentiation of technological innovation's contribution to productivity was also observed in the service sector. For example, in 2006-2008 PPI's effect reached significant positive values for British and German service companies, while in Ireland such firms steadily increased their productivity by applying only process innovations (Peters et al., 2018). The roles of both innovation types also significantly differ between large regional country groups: PPI's impact, including the combined one, on productivity in Latin America and the Caribbean in 2002-2016 was 3-4 times higher than the relevant figures for Eastern European (including Russia) and Central Asian countries (Morris, 2018).

[2] Original equipment manufacturers are firms that make parts and equipment that can be sold by other manufacturers under a different brand name.

The differentiation of PPI impact by industry is much higher than by country. In the Brazilian manufacturing industry, technological innovations did not significantly affect the growth of sales in 2000-2002 except for the high-tech sector, where process innovations had a pronounced negative impact (Goedhuys, 2007). PPI impact on labor productivity in the French service sector in 2002-2004 was four times higher, while the cumulative effect was 1.5 times higher than in the manufacturing industry (Miresse, Robin, 2008). Similarly, in Ireland in 2004-2008 the tertiary sector companies were 2-2.5 times ahead of manufacturing ones in terms of the parameters in question (Siedschlag et al., 2010). In Chile in 2005-2008, product innovations made a strong negative impact, while process innovation, on the contrary, positively affected performance in the industry. At the same time, in the service sector their contribution was generally negligible. The exception was knowledge-intensive business services, where the role of process innovation turned out to be significantly positive (Alvarez et al., 2015).

The dominant innovation type appears to be unrelated to the previous development path, as evidenced by the studies of large country samples comprising developed and transition economies. The results of the 2004 European enterprise survey showed that process innovations, developed both in-house and in partnership with other players, make a key contribution to improving productivity in advanced Western European countries (Hashi, Stojcic, 2013). At the same time, in the CEE, transition economies jointly created process innovations that did not significantly affect productivity, while in-house ones even had an appreciable negative effect. A similar situation is typical for product innovations: in Western European countries they played an important, positive, and statistically significant role, which cannot be said about CEE.

Do these results mean that an economic growth mechanism insensitive to innovation has emerged in CEE? The data for 2013-2014 (Ramadani et al., 2018), however, indicates that product innovations make a high positive contribution to the region's countries' productivity, which refutes the above supposition.

Such a contradictory picture is largely due to the limited time interval covered by most studies, which have to rely on data from numerous firms for the same period (cross section). This is a specific distortion of statistical surveys of innovation activities, which aggregate data for the last three years. Even in the case of a repeat survey, the company sample is usually not maintained (Hall, 2010). As a result, each company's uniqueness (unobserved heterogeneity) is either taken into account insufficiently, or not at all (Crowley, McCann, 2018), despite this factor's fundamental importance for understanding company performance (De Loecker, 2011).

Unsurprisingly, the few studies comprising several rounds and covering more than one time period reveal changes in the PPI's impact over time. For example, there are notable differences between the 1998-2000 and 2002-2004 manufacturing industry surveys in France and Estonia (Mairesse, Robin, 2008; Masso, Vahter, 2008). In the case of France, process innovations dominated during the first period, making an increasingly positive impact upon productivity, while in the second period, this role shifted to product innovations. In Estonia, a significant positive effect was initially recorded only for product innovations, and then only for process ones.

Results like that refer to classic studies (Schumpeter, 1934; Abernathy, Utterback, 1978), which describe innovation cycle models based on alternating PPI, radical and improving ones alike. Applying quantile regression to several samples of the Chilean economy revealed that process innovation yields a significant positive effect only for firms with the lowest or highest sales dynamics (Santi, Santoleri, 2017), but not for companies with median values of this indicator. An analysis of a large sample of small and medium-sized German manufacturing enterprises for 2005-2012 (Baumann, Kritikos, 2016) demonstrated that product innovations make the greatest impact upon business performance of the smallest companies (with less than 10 employees), and it (impact) decreases as company size grows. Thus, even if at a particular moment in time the economic development may be mainly driven by innovations of a certain type, this does not mean the scenario cannot quickly change as the leading industries move through the cycle phases.

This refutes the second and third hypotheses.

Let us more precisely define the place of PPI in the economic cycle of goods and services production. Although innovation is just one of many factors whose inclusion in the correlation equation can significantly change the final estimates, there appears to be no strict inverse relationship between the number of factors taken into account and the strength of PPI's impact. For example, (Arvanitis, 2006) obtained significant and high elasticity values for the effectiveness of PPI on the basis of 13 factors. (Chudnovsky et al., 2006) analyzed 18 factors and found that process innovation played a significant and positive role with a complementary PPI effect. The increased impact from both innovation types if a larger number of factors was taken into account is documented in (Mairesse, Robin, 2008; Hashi, Stojcic, 2013; Martin, Nguyen Thi, 2015; Lin et al., 2016; Vakhitova, Pavlenko, 2010; Alvarez et al., 2015; Edeh, Acedo, 2021; Baumann, Kritikos, 2016).

The PPI effect's sensitivity to introducing additional variables into the model is due not to the number, but to the nature of the factors. The commonly applied science and technology indicators traditionally associated with innovation (which not infrequently

Table 1. **Studies of Product and Process Innovations' Impact on Productivity**

Source	Countries, years	Methodology	Sample	Number of observations	Dependent variable	Innovations' impact on dependent variable		
						Product	Process	Product and process
(Huergo, Jaumandreu, 2004), p. 549, T. 1A	Spain, 1991–1998	Nadaraya-Watson non-parametric kernel estimation	M and MA, all	10735	TFP growth rate	—	0.015***	—
			M and MA: I	7293		—	0.0003	—
(Arvanitis, 2006), p. 28, T. 3.	Switzerland, 1996, 1999, 2002	CDM, 2LSM, PM	MA	1691	LP	0.500***	0.454***	—
		CDM, generalized 2LSM, RE				0.552***	0.411***	—
(Chudnovsky et al., 2006), p. 286, T. A. 3	Argentina, 1992–2001	CDM, LSM, FE	MA	1410	LP	0.088	0.178**	0.136**
(Parisi et al., 2006), pp. 2047–2048, TT. 5–6	Italy, 1995 and 1998	IVM: individual product and process innovations' effects	MA	465	LP growth rate	–0.05	0.17*	—
		IVM: process innovations' effect				—	0.14**	—
		IVM: product innovations' effect				0.08	—	—
		IVM: process innovations' effect adjusted for average knowledge intensity				—	0.11*	—
		IVM: individual product and process innovations' effects		459	TFP growth rate	0.04	0.12	—
		IVM: process innovations' effect				—	0.15**	—
		IVM: product innovations' effect				0.13*	—	—
		IVM: process innovations' effect adjusted for average knowledge intensity				—	0.12*	—
(Griffith et al., 2006), p. 492, T. 5	France, 1998–2000	CDM, IVM	MA	3625	LP	0.060***	0.069**	—
	Germany, 1998–2000	CDM, IVM		1123		–0.053	0.022	—
	Spain, 1998–2000	CDM, IVM		3588		0.176***	–0.038	—
	UK, 1998–2000	CDM, IVM		1904		0.055**	0.029	—
(Goedhuys, 2007), pp. 25–26, TT. 4, 5.	Brazil, 1997, 2000–2002	LSM, PM, not adjusted for available patents	MA	1352	TFP	0.030	–0.102***	—
		LSM, PM, adjusted for available patents				0.016	–0.079**	—
		LSM, PM	MA all firms	1061	Growth of sales	0.001	–0.008	—
			MA: T	529		–0.003	–0.007	—
			MA: I	530		–0.000	–0.042**	—
(Mairesse, Robin, 2008), T. 5.	France, 1998–2000	CDM, ML	MA	3524	LP	0.570***	1.120**	0.520***
	France, 2002–2004		MA	4955		1.090***	0.310	0.350***
			S	3599		3.750***	1.440***	0.590***
(Masso, Vahter, 2008), p. 254, T. 8.	Estonia, 1998–2000	CDM, 2LSM, no time lag	MA	853	GVA	0.207**	–0.055	—
		CDM, 2LSM, one-year lag		855		0.146*	0.046	—
		CDM, 2LSM, two-year lag		862		0.181**	–0.067	—
	Estonia, 2002–2004	CDM, 2LSM, no time lag		676		0.002	0.151***	—
		CDM, 2LSM, one-year lag		635		–0.014	0.169***	—

Table 1 continued

Source	Countries, years	Methodology	Sample	Number of observations	Dependent variable	Innovations' impact on dependent variable		
						Product	Process	Product and process
(Hall et al., 2009), p. 25, T.5.	Italy, SMEs, 1995–2003	CDM, 3LSM not adjusted for investments	MA: all	9674	LP	0.961***	2.624***	—
		CDM, 3LSM adjusted for investments				0.597***	0.193	—
		CDM, 3LSM not adjusted for investments	MA: HT firms	2870		1.314***	2.742***	—
		CDM, 3LSM adjusted for investments				0.700***	0.664	—
		CDM, 3LSM not adjusted for investments	MA: LT firms	6804		0.900***	2.797***	—
		CDM, 3LSM adjusted for investments				0.708***	0.063	—
(Musolesi, Huiban, 2010), p. 73, T.4	France, 1998–2000	CDM, ML according to Heckman (1978) and Maddala (1983)	KIBS	416	GVA	0.324***	0.131	—
		CDM, 2LSM				0.247*	0.301	—
		CDM, IVM according to Wooldridge (2002)				0.271*	0.294	—
(Vakhitova, Pavlenko, 2010), p. 29, T.5.	Ukraine, 2004–2006	CDM, IVM, CSM	MA	792	LP	–0.205	1.137***	—
(Siedschlag et al., 2010), TT. 5, 8, 11.	Ireland, 2004–2008	CDM, IVM, RE	MA and S	1446	LP	0.452***	0.334***	0.271***
			MA	732		0.257**	0.213**	0.163**
			S	714		0.609***	0.450***	0.419***
(Goedhuys, Veugelers, 2012), P. 526, T. 5.	Brazil, 2000–2002	CDM, 2LSM, FE, no PPI complementarity	MA	1503	Average LP growth rate	0.357***	0.014	—
		CDM, 2LSM, FE, PPI complementarity		1503		0.279	–0.071	0.348***
(Hashi, Stojcic, 2013), p. 363, T. 7.	Western, Central and Eastern Europe, 2004	CDM, 2LSM, in-house developed innovations	MA and S	15644	LP	0.528***	0.534***	—
		CDM, 2LSM, innovations developed jointly with other companies				0.266**	0.242**	—
	Western Europe, 2004	CDM, 2LSM, in-house developed innovations		10200		0.904***	1.171***	—
		CDM, 2LSM, innovations developed jointly with other companies				0.581***	0.509***	—
	Central and Eastern Europe, 2004	CDM, 2LSM, in-house developed innovations		5444		0.156*	–0.301***	—
		CDM, 2LSM, innovations developed jointly with other companies				0.052	–0.011	—
(Acosta et al., 2015), p. 59, T. 5.	Spain, 2008–2011	CDM, IVM	MA	1910	LP	0.315***	0.099	0.224***
Alvarez et al., 2015), p. 609, T. 10.	Chile, 2005–2008	CDM, IVM	MA	2679	LP	–4.148**	5.159***	—
			S	3985		2.630	–1.566	—
			KIBS	1572		–3.729	5.155*	—
			TS	2413		1.186	2.191	—
(Ballot et al., 2015), p. 224, T. 3.	UK, 2002–2004	Heckman method	MA	3627	LP	—	—	0.880***
	France, 2002–2004		MA	5691		—	—	0.758***

Table 1 continued

Source	Countries, years	Methodology	Sample	Number of observations	Dependent variable	Innovations' impact on dependent variable		
						Product	Process	Product and process
(Martin, Nguyen Thi, 2015)	Luxembourg, 2004–2006	CDM, ML adjusted for knowledge-intensity	MA and S	364	LP	0.367	0.934*	—
		CDM, ML adjusted for knowledge-intensity and rate of ICT use		364		0.573*	1.380***	—
(Baumann, Kritikos, 2016), p. 36, T.VI.	Germany, SMEs, 2005–2012	CDM, LSM, PM	MA: all	16579	LP	1.258**	0.415	—
			MA: less than 10 empl.	4463		2.610**	–1.878	—
			MA: at least 10 empl.	12116		1.275**	0.394	—
(Lin et al., 2016), p. 160 T. 6 , p. 162 T.7, p. 163 T.8.	Taiwan, 2004–2006	CDM, IVM	MA	1016	TFP growth rate	–1.081	2.913**	0.385
				1046	LP growth rate	–2.006	3.219*	0.045
			MA: OEM	292	TFP growth rate	—	1.708	5.875***
			MA: non-OEM	217		—	1.900	–0.286
			MA: OEM	295	LP growth rate	—	1.352	7.535***
			MA: non-OEM	220		—	0.102	1.764
(Santi, Santoleri, 2017), p. 458, T. 4.	Chile, 2007, 2009, 2012	LSM, PM with lag regressors	MA and S	3336	Growth of sales	0.013	0.025***	—
		LSM, FE with lag regressors				–0.038**	0.017	—
		Quantile regression with lag regressors, 10% quantile				–0.037	0.050**	—
		Quantile regression with lag regressors, 25% quantile				0.001	0.017	—
		Quantile regression with lag regressors, 50% quantile				–0.005	0.015*	—
		Quantile regression with lag regressors, 75% quantile				–0.002	0.026***	—
		Quantile regression with lag regressors, 90% quantile				–0.022	0.042***	—
(García-Pozo et al., 2018), p. 1055, T.5.	Spain, 2008–2013	CDM, IVM	S	22620	LP	0.132***	0.022***	—
(Peters et al., 2018), p. 607, T.5.	Germany, 2006–2008	CDM, IVM	S	1333	LP	0.163***	0.211***	—
	Ireland, 2006–2008			1256		0.089	0.174*	—
	UK, 2006–2008			4346		0.043*	0.065**	—
(Ramadani et. al., 2018), p. 278, T.4.	Central and Eastern Europe, 2013–2014	CDM, IVM	MA and S	2109	LP	0.862**	—	—
(Edeh, Acedo, 2021, p. 8, T. 5.	Nigeria, 2005–2010	CDM, IVM	MA and S	417	LP	2.850***	7.020***	—

* — significance at a 10% level; ** — significance at a 5% level; *** — significance at a 1% level;

Legend:
MI — mining industry; MA — manufacturing industry; HT — high-tech companies; LT — low-tech companies; S — services; KIBS — knowledge-intensive business services; TS — traditional services; T — traditional sector; I — innovation sector; SME — small and medium enterprises; OEM — original equipment manufacturers; IVM — instrumental variables method; LSM — least squares method; 2LSM — two-step least squares method; 3LSM — three-step least squares method; ML — maximum likelihood estimator; PM — pooled sample model; CSM — cross-sectional sample model; FE — fixed effects model; RE — random effects model; CDM — Crepon-Doget-Myriss model (Crepon et al., 1998); LP — labor productivity (sales per employee); TFP — total factor productivity

Source: author.

Table 1a. **Estimation of Product and Process Innovations' Impact on Productivity undertaken in (Morris, 2018)**

Countries, years	Methodology	Sample	Number of observations	Dependent variable	Innovations' impact on dependent variable		
					Product	Process	Product and process
Eastern Europe, Central Asia, Latin America and the Caribbean 2002–2016	CDM, LSM, CSM	MA and S	8906	LP	0.284***	0.168**	0.166**
	CDM, LSM, FE		8906		0.304***	0.134*	0.161*
Eastern Europe and Central Asia, 2002–2016			3096		0.164*	0.219***	0.125
Latin America and the Caribbean, 2002–2016			4831		0.683***	0.698**	0.728**
Eastern Europe, Central Asia, Latin America and the Caribbean, 2002–2016		MA	8816		0.292***	0.152**	0.120
Eastern Europe, Central Asia, Latin America and the Caribbean, 2002–2016		S	16810		0.927***	0.787***	1.560***
Eastern Europe, Central Asia, Latin America and the Caribbean, 2002–2016	CDM, LSM, CSM	MA and S	8908	TFP (Olley, Pakes, 1996)	0.483**	0.486**	0.582**
Eastern Europe, Central Asia, Latin America and the Caribbean 2002–2016	CDM, LSM, FE		8908		0.324**	0.108	0.275*
Eastern Europe and Central Asia, 2002–2016			8908		0.243***	0.071	0.157*
Latin America and the Caribbean 2002–2016			8908		0.438*	0.081	0.487*
Eastern Europe, Central Asia, Latin America and the Caribbean 2002–2016		MA	8908		0.204**	–0.016	0.179*
Eastern Europe, Central Asia, Latin America and the Caribbean 2002–2016		S	8908		0.172**	0.107**	0.098
Eastern Europe, Central Asia, Latin America and the Caribbean 2002–2016	CDM, LSM, CSM	MA and S	8908	TFP (Levinsohn, Petrin, 2003)	0.456**	0.470**	0.558**
Eastern Europe, Central Asia, Latin America and the Caribbean 2002–2016	CDM, LSM, FE		8908		0.301**	0.116*	0.270**
Eastern Europe, Central Asia, 2002–2016			8908		0.212**	0.023	0.116
Latin America and the Caribbean, 2002–2016			8908		0.340*	0.084	0.395*
Eastern Europe, Central Asia, Latin America and the Caribbean, 2002–2016		MA	8908		0.181**	–0.025	0.152
Eastern Europe, Central Asia, Latin America and the Caribbean, 2002–2016		S	8908		0.093	0.063*	0.007

Note: for the Legend see Table 1

Source: author.

substitute it) cannot significantly affect the estimates of the impact under consideration. For example, in Italy (Parisi et al., 2006) process innovations' contribution to the growth of labor and total factor productivity (TFP) remained practically unchanged after the equation was adjusted for average knowledge intensity, and in Brazil (Goedhuys, 2007), after the patent activity was taken into account.[3] Thus, a distinction should be made between science and technology activities on the one hand, and innovation on the other. The latter has pronounced economic specifics, so it would not be correct to approximate it through R&D expenditures or the number of patents issued. An innovative firm may not conduct R&D at all or it may not patent the results obtained.

A study based on Luxembourg data (Martin, Nguyen Thi, 2015) found that the effect of process innovation adjusted for knowledge intensity can be strong

[3] Notably, (Parisi et al., 2006) reported the positive effect of process innovation, while (Goedhuys, 2007) reported a negative one.

and statistically significant. If we also take into account the rate of ICT use, an increase in productivity growth is guaranteed. However, this pattern is not universal: in developing countries innovation activity can be closely correlated with the level of computerization, communication facilities, and infrastructure, which will devalue the economic effect of innovation if variables reflecting the use of ICT are introduced.

It was also demonstrated for the relatively developed Italy that adjusting equations for the amount of investments significantly affects the contribution of process innovations to labor productivity growth (Hall et al., 2009). If without taking this factor into account the impact of this innovation type turns out to be significant (at 2.6-2.8, and increasing) when considered, the impact becomes statistically insignificant. This is true for both high-tech and low-tech industries, i.e., it seems to be a universal pattern, at least for Italy. Firms engaged in process innovation invest in new equipment, which leads to collinearity of indicators. Adjusting for investment also appreciably changes labor productivity's elasticity for product innovations, though the latter remain a powerful and significant factor.

Thus, the fifth hypothesis was partially confirmed.

Future Research Areas

In our opinion, the most problematic areas of the entire body of studies that address PPI's impact on productivity are identifying and meaningfully interpreting "growth points" – environmentally localized segments of the national economy where innovation activity is high, and developing generally accepted methods for the econometric assessment of impact coefficients.

In a number of studies, PPI's contribution to productivity growth in the sectors traditionally seen as innovation development drivers is assessed as insignificant or even negative. In particular, an analysis of a large sample of Spanish mining and manufacturing enterprises for 1991-1998 revealed that process innovations served as a significant driver of TFP growth in all national industries except high-tech ones (Huergo, Jaumandreu, 2004). According to the calculations presented in (Goedhuys, 2007), in the Brazilian manufacturing industry, high-tech process innovations had a statistically significant, slightly negative impact on sales growth.

A strikingly high or low PPI effect in a particular sector can be interpreted in several competing ways. How, from an economic point of view, should the excess or decline of PPI's impact (combined or individual) on productivity at time t be correctly estimated taking into account all statistical flaws and methodological limitations? Does such an effect provide an actual advantage compared to economies (or industries, or enterprises) where it is not observed? What opportunities or limitations for the growth of the national industry and the service sector do such effects create? How long can they and/or should they exist in a regional/industry niche, and what factors affect the length of this period?

In studies which tried to make such assessments based on data from France for 2002-2004 (Mairesse, Robin, 2008), Western Europea for 2004 (Hashi, Stojcic, 2013), Luxembourg for 2004-2006 (Martin, Nguyen Thi, 2015), Taiwan for 2004-2006 (Lin et al., 2016), Ukraine for 2004-2006 (Vakhitova, Pavlenko, 2010), Chile for 2005-2008 (Alvarez et al., 2015), Nigeria for 2005-2010 (Edeh, Acedo, 2021), and Germany for 2005-2012 (Baumann, Kritikos, 2016), meaningful interpretation of the econometric results was simply omitted. Meanwhile, we are talking about very different economies at different phases of their economic cycle. Even applying relevant econometric analysis techniques to the same sample of enterprises (statistical survey results) often yields widely different outcomes.

For example, two studies analyzed a sample of the French manufacturing companies for 1998-2000 (Griffith et al., 2006; Mairesse, Robin, 2008). Though both of them were conceptually based on the CDM model[4] (Crepon et al., 1998) and demonstrated a statistically significant positive correlation between the application of PPI and labor productivity, differences in econometric techniques led to a radical mismatch in the level of the obtained estimates. Whereas in (Griffith et al., 2006) the elasticity of productivity to PPI was estimated at 0.06-0.07, in (Mairesse, Robin, 2008) it was 0.6-1.1. Thus, from an unremarkable (but statistically significant) factor, PPI turns into one of the most important economic development drivers of the same firms at the same time.

Opposite examples are also known, when changing the methodology did not significantly affect calculation results. However, all such cases were reported in individual studies that were not verified or revised in other works. A similar French sample for 1998-2000, but of the specific knowledge-based business services companies (Musolesi, Huiban, 2010) was analyzed using several econometric techniques. The authors found that regardless of the assessment method, product innovations were a strong factor that increased added value, while process ones did not make a significant impact. On the basis of Swiss manufacturing industry data for 1996, 1999, and 2002 (Arvanitis, 2006), it was demonstrated that a

[4] The CDM (Crépon-Duguet-Mairesse) model takes into account three main innovation process stages: making a decision to invest in R&D, applying the innovations, and productivity.

high positive elasticity of productivity to both innovation types remained robust to changes in the panel regression assessment method.

Contradictory conclusions also follow from comparing calculations based on different productivity variable indicators.

In a number of cases PPI affected various performance indicators in approximately the same way. For example, in (Parisi et al., 2006) performance in the Italian manufacturing industry in 1995 and 1998 was estimated via labor productivity and TFP growth rates. It was established that both these indicators experienced a statistically significant positive impact from process innovation, including in equations adjusted for the average knowledge intensity. However, the growth in TFP was also significantly affected by product innovation, while its contribution was insignificant in equations that used labor productivity growth rates. Similar performance indicators were applied in (Lin et al., 2016). The authors found the results to be equally consistent. The performance of the Taiwanese manufacturing industry in 2004-2006, in terms of both labor productivity and TFP growth rates, was strongly positively affected by process innovation, while product innovations' contribution was insignificant. The same applies to the complementary PPI effect, which for original equipment manufacturers was obviously statistically significant. This also holds true for both labor productivity and TFP equations.

Meanwhile PPI impact assessments based on labor productivity and TFP generally tend to be different, as indicated, in particular, by the detailed set of calculations presented in (Morris, 2018): a major study of 40,500 enterprises from 43 developing countries (in Eastern Europe, Central Asia, Latin America, and the Caribbean) for 2002-2016. The estimates of PPI's impact on labor productivity and TFP obtained with the help of the Olley-Pakes method (Olley, Pakes, 1996), and on TFP with the help of the Levinson-Petrin method (Levinsohn, Petrin, 2003) have pronounced discrepancies between them. The high positive values of labor productivity elasticity to PPI were found first of all in the service sectors of the countries included in the sample. The complementary PPI effect on labor productivity in the service sector even exceeds 1, which suggests an economy of scale-like increase due to the synergy of the two innovation types. Thus, service innovations appear to be a key development driver for a significant proportion of the world's economy.

As to PPI impact's on TFP, the tertiary sector's role no longer looks exclusive. Product and process innovations alike had a small positive effect on the TFP of the relevant companies in the sample, calculated using the Olley-Pakes method (Olley, Pakes, 1996). On the other hand, if TFP was measured using the Levinson-Petrin method (Levinsohn, Petrin, 2003), only process innovations appeared to make a small positive impact. The complementary effect on TFP in the service sector measured by the both methods was statistically insignificant. In the manufacturing industry, it turned out to be weakly significant only when the Olley-Pakes toolkit was applied (Olley, Pakes, 1996).

Conclusion

Technological innovations make a tangible contribution to increasing companies' productivity, which can be reliably measured with various modern economic research methods. However, these approaches have certain limitations. In particular, what is actually measured is not the effect of PPI, but the "innovativeness" of companies which apply product or process innovations, individually or in combination (complementarity). While product innovations can be expressed in value terms (sales of goods), the effect of process innovations estimated with binary variables only tends to be negative, regardless of the sample and calculation technique (which in fact requires a separate analysis). A firm is considered to be innovative if it has implemented innovations during the previous three years. This is believed to be important for productivity growth, regardless of other closely related factors such as R&D, patenting, and staff training.

Also, the spatial distribution and dynamics of PPI's effects are much better explained by classic innovation cycle theories than by modern concepts of innovation in high- and low-tech industries. Accordingly, the need to develop new relevant theories comes to the fore. The innovation type predominant in terms of productivity impact is not country- or industry-specific, but mainly depends on the innovation cycle phase. Therefore, if the objective is to step up productivity, it would be incorrect to *a priori* rely on, for example, product innovations in a high-tech industry, as certain countries seem to be doing. The same is true for the complementary effect of PPI: studying the accumulated data array did not reveal that combining these two innovation types has an obvious practical value. On the contrary, there is evidence that the complementary effect of PPI can be statistically insignificant.

When predicting PPI's effects, one should distinguish between the impact innovations make on various aspects of companies' and industries' activities, if possible applying several statistical methods to evaluate it. Minor product innovations can make a tangible positive contribution to sales growth, but do not affect labor productivity or TFP at all. Similarly, a radical capital-saving process innovation will produce modest observable results when measured in terms of short-term labor productivity growth.

The effectiveness of PPI as a productivity driver can easily become an object of statistical manipulations, which may have a particularly painful effect on the ideology behind and the results of state innovation policy.

Finally, due to the reasons described above the mechanics of technological innovations' interaction with productivity, despite the century-long experience in evaluating the relevant indicators and their relationships, remains a kind of "thing in itself". The state should contribute to increasing and maintaining the level of innovation activity in economic sectors and regions. But which sectors and regions, specifically? Which innovation types (product, process, organizational, marketing, etc.) would be more effective to focus on if the industry allows one to apply different ones? Should a pronounced positive (negative) correlation between innovation and productivity always be interpreted as a positive or negative result? Perhaps the current generation of empirical innovation studies based on enterprise surveys (a subject-based approach) cannot provide meaningful answers to such questions in principle. In that case, international science will have to develop new ways of measuring innovation, just as the subject-based approach (enterprise surveys) since the early 1990s began to dominate patent statistics, which in its turn has replaced R&D statistics in the 1960s and 1970s.

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The Contradictory Role of Corruption in Corporate Innovation Strategies

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Abstract

This study considers the influence of the work experience of Russian top managers on the willingness to stimulate innovative processes at companies, including through the use of some corruption schemes to bypass bureaucratic barriers at a certain stage. Using a logit model based on enterprise surveys carried out by the World Bank, data on the managers of small and medium-sized businesses were analyzed.

It was revealed that the presence of "corruption competencies" has a positive effect on the innovative activity of enterprises in developing countries. This effect is due to the fact that corruption in such countries acts as a mechanism to reduce the transaction costs associated with innovation. The level of corrupt activity of managers increases as they accumulate experience due to the high degree of bureaucratization and the weakness of institutions, which turn into time and financial costs for enterprises. In the short term, corruption can accelerate the development of innovation, but it cannot serve as a permanent tool in this regard, since its long-term consequences turn out to be extremely negative

Keywords: innovation; top-level management experience; corruption; SMEs; bureaucracy; Russia
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Introduction

Innovation is the driver for the growth of small and medium scale enterprises. It ushers them into the competitive market, creating new markets and new avenues for employment. The support of top management is absolutely essential for innovation (e.g., Ollila, Yström, 2016). The question therefore is "Does the experience of the top manager have an infuence on innovation?" And if so, "Does this experience influence any form of corruption?"

One of the main prerequisites for economic and innovative development in accordance with the new institutional theory (North, 1992) is the quality of institutions that determines the magnitude of transaction costs (Coase, 1991). The choice of a legitimate path or an alternative corrupt way of developing the firm thus boils down to the theory of opportunity costs, thus justifying the optimality of the path with minimal costs (Parkin, 2016).

Theoretical assumptions about the complex role of corruption are confirmed in the economic literature. Corruption is known to have a negative impact on socio-economic development (Xiao et al., 2018). In developed countries, corruption worsens the quality of institutions and negatively affects the development of startups (Woodside et al., 2016). Due to this, governments have taken extreme measures to curb this effect. Due to this, the government of Russia and regional governors have taken a keen interest in the subject. They have implemented local anti-corruption legislation.[1] This action has further been enforced by the Higher School of Economics with their campaign to eradicate corruption from society. The International Anti-Corruption Academy has two courses (1) a course on using asset disclosure to detect indicators of corruption and a course on handling conflicts of interest in the public sector. The aim of these courses is to educate the students and the future leaders about the implications of corruption. Even though there are tough measures by the state to eliminate corruption, there is still the presence of corruption at the micro level.

Cultural factors and moral values are within the institutional environment surrounding top managers as the main agents of firm innovation (Cannella et al., 2009). Conducting innovations at a lower cost is one of the core competencies of company management (Carney et al., 2019) according to the theory of the upper echelon for the strategic development of companies (Hambrick, Mason, 1984).

In this article, based on the theory of upper echelon, we justify the increase in corruption competencies of top managers with increasing experience, which in turn, in accordance with the theory of transaction costs and opportunity costs, contributes to the negative impact of corruption upon innovation activity. We empirically verify our theoretical and methodological justifications using data from a survey of World Bank enterprises using the Logit model for Russia, which in 2015 ranked 119th in the corruption perception index.

Our contribution lies in the fact that, based on the institutional theory and the theory of the upper echelon, we prove the effect of the development of managers' corruption competencies with growing experience in innovative activity for enterprises in developing countries.

Our article is structured as follows. First, we describe the theories of innovative activity of firms and characterize the main determinants of innovation. Then there are the results of previous work in the field of institutional economics and the theory of the upper echelon, which is the theoretical basis for our research. Then, within the methodology section, we will justify and formulate hypotheses, characterize the variables included in the model, present the results of our modeling, and draw conclusions from our model. At the end of our article, we formulate conclusions.

Managers and Corruption

Corruption has become a means to an end to a lot of multinational companies, which is fostered by top managers. Corruption is the main threat in many countries around the world. It is a phenomenon that a lot of countries are trying to eradicate or minimize in their modern societies, but it still persists due to institutional weakness, selflessness on the part of individuals and organization, and inadequate rule of law. Multinational corporations have become richer and more powerful due to illegal bribery and kickbacks to government officials to exploit new markets, illegally pollute countries, and obtain large contracts at exorbitant costs. The corporation exploits the weaknesses in a system to get as much as it can from the system, corruption is not a one-way phenomenon. There are always two parties who stand to gain from such transactions, the corporation and the corrupt official as indicated in fraud literature (Zahra et al., 2005). Even as the top manager remains an instrumental part of corruption, there is no research looking at the interaction between top managers and corrupt officials.

The theoretical basis for the study of corruption in our work is the theory of transaction costs by Coase (1937). The nature of the firm impacts the activities of firms, including innovative ones. Institutions play a key role in determining transaction costs (North, 1992), which makes their quality important determinants for economic development, and, consequently, innovation activity. Solving the problem of transac-

[1] E.g. the Law of the Moscow City No. 64 On Fighting Corruption, 2014.

tion costs in business, an entrepreneur is faced with the question: should he follow the law or is it more profitable for him to circumvent the law using other methods. The solution of the issue is based on the theory of opportunity costs (Parkin, 2016), according to which the entrepreneur chooses the path with the minimum cost. Thus, whether an enterprise will use corrupt ties or will carry out its activities within the framework of the law is determined by the amount of alternative transaction costs, which in turn is due to the quality of institutions.

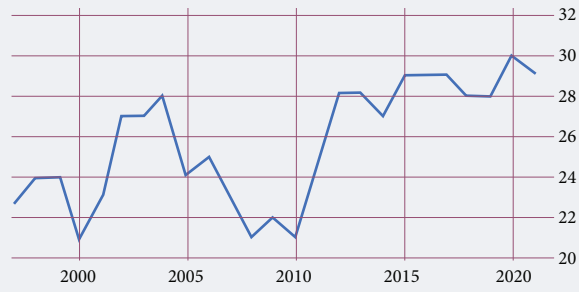
Research by the Institute for Public Administration and Governance (IPAG) of the Higher School of Economics National Research University in Moscow conducted a research study interviewing 1,200 businesses. In the sample, 53% of respondents are from microenterprises, 34% are from small businesses, 6% are from medium-sized, and about 7% are from large firms. The scientists asked not only direct, but also indirect questions (for example: "What do you think determines whether companies pay informally in public procurement?"). Based on the respondents' answers to indirect questions, the researchers found that at least two out of three companies indicated the existence of informal payments to customer representatives, 28% found it difficult or refused to answer. The amounts ranged from 3% to 65% of the cost of the state contract.[2] We see two faces of corruption in this case, a business taking advantage of an institution to eliminate competition and an individual using his or her position to enrich himself or herself. The bureaucrats in favor of their own interests increase the red tape rates above the level that would be socially acceptable, which leads to bribes being paid in order to overcome bureaucracy-related obstacles (Guriev, 2004). When competition is eliminated, it goes a long way in impacting the startup ecosystem and making entrepreneurs suffer long term.

The Anti-Corruption Campaign in Russia

The Russian anti-corruption campaign is an ongoing effort by the Russian government to curb corruption, which has been recognized as one of Russia's most serious problems.

Figure 1 shows the rank of the corruption perceptions index and Russia is among the countries with the highest scores, which has prompted the government to take serious action against such acts. Russia has released a National Anti-Corruption Plan for 2021–2024, which is the longest plan the country has undertaken since it started its anti-corruption campaigns. The new plan is divided into 16 areas to cater for the gaps in the previous plan. The Higher School of Economics (HSE) has also been a strong mouthpiece for the anti-corruption campaign. Even though

Figure 1. **The Dynamics of the Corruption Perceptions Index**



Source: authors.

the problem persists, there is willingness on the part of the government and educational institutions to work hand-in-hand to fight this.

Innovation and Corruption

Corruption has a complex relation with innovation, it is more of a heterogeneous relationship than is indicated in the literature. Greasing and sanding may actually coexist in transition and emerging countries, depending on the level of analysis, and other related factors (Iorio, Segnana, 2022). Corruption and innovation theories tell us that they are highly dependent on societal circumstances, such as mentality, which includes the traits of a history or political system. Corruption reduces aggregate efficiency in countries where institutions are effective, yet increases efficiency where institutions are ineffective (Meon, Weill, 2010). Strong institutions show negative effects of corruption while transitional countries with weak institutions show the positive effects of corruption on innovation. An empirical analysis for a maximum of 43 countries over the 2003–2005 period shows that corruption can indeed be beneficial. At the maximum level of regulation, public corruption increases private entrepreneurial activity significantly (Dreher, Gassebner, 2013). The East Asian paradox, which is a greasing puzzle with high levels of corruption but very rapid economic growth, is a puzzle treated at the micro-level for Chinese firms (Wang, You, 2012) with empirical evidence that corruption enhances the growth of revenue and boosts innovative activities by Chinese firms. Krammer (2019) explores the micro evidence in emerging countries, providing evidence of the positive effects of petty corruption on developing new products in transition economies. There is other research that shows the negative effect of corruption on innovation and economic growth.

The effect of corruption is a two-way effect as has been stated and justified in the literature. The effect of cor-

[2] https://www.rbc.ru/economics/20/12/2021/61bc5d059a794770833e7b51, accessed 12.03.2022.

ruption and its intensity is subject to mostly historical, political, and cultural situations in the country. These factors tend to reflect in the results of corruption research, since all political and socioeconomic situations are not the same, it is difficult to come to a single conclusion about corruption. To fight corruption is to work on institutional efficiency and the easing of barriers for startups and minority groups who tend to face the full brunt of harsh regulations.

The Top Echelon as the Creator of Innovation

The basis of the theory of the upper echelon is the study of the qualities of managers and their impact on the company. The upper echelon theory (Hambrick, Mason, 1984) suggests that organizational strategic choices are a function of the composition of an organization's dominant coalition. The compositions of top managers' observable characteristics influence the organizational outcomes through their strategic choices. The burden of the entire firm rests on the shoulders of the top executives. Top managers are people in the firm whose decisions directly lead to the firms engaging in certain behaviors (Hitt, Collins, 2007) that influence corruption and innovation. Leaders, through their personal beliefs and ethics, create an environment that promotes or kills innovation. Truth Social created by Donald Trump is a clear example of a leader's personal beliefs influencing innovation. The approval of the manager is essential for growth and innovation. Corporate management affects innovations by often setting the boundaries of what is acceptable to build and what is not as well as the provision of funding. As such, appealing to corporate management is critical, which makes the role of top managers imperative as the overseers of innovative activities.

Top management creates an environment that promotes employees' awareness of themselves as part of a social community and creates incentives for cooperation, which ultimately positively affects the innovative activity of a company (Langner, Seidel, (2015). On the other hand, excessive control by top management negatively impacts the innovative activity of companies (Hoskisson, Hitt, 1988). External control is negatively affected, but the firm's internal control does not affect R&D (Yin et al., 2019). An innovation-friendly environment is created by managers with greater faith in success and those that do not overestimate the risk of failure. The corporate fraud literature suggests that top managers often are the drivers of firms' engagement in illegal activities (Zahra et al., 2005). Such engagement in illicit activity has been fostered by top managers' desire to cut costs and time. Firms seek to avoid or accelerate approvals via a corrupt payment (Martin et al., 2007). Scholars have shown that the amount of time managers spend dealing with government officials is linked to the extent of corrupt transactions. For top managers to ensure they meet targets, they often go above and beyond, which can mean engaging in questionable practices.

Institutional Determinants of Innovation

Institutional determinants, in particular cultural heritage, determine the managerial competencies of top managers, who in turn increase the efficiency of firms and their innovative activity (Lau, 2011). Cultural factors and moral values are the institutional environments surrounding top managers as the main agents of firm innovation (Cannella et al., 2009). The ability to innovate at a lower cost is a "lean innovation" that is characteristic of family businesses. At the same time, the ability to carry out innovations at lower costs is preserved in firms with family succession (Carney et al., 2019). Further, family management for the company can lead to higher-level splits, which will lead to less innovation and lower efficiency (Minichilli et al., 2010).

In viewing strategy and in interpreting strategic possibilities, members of the organization's upper echelons inevitably do so through the lens of their personal experiences, values, personalities, and other similar human factors. Because top executives stand at the mercy of the stakeholders, they try to be innovative and use every means necessary to stay relevant on the market. This echoes the relevance of experience and networks of the top management which also influence corruption.

At the same time, the question remains how the experience of managers influence their corruption actions, i.e., the ability to use informal relations with officials for the innovative activity of their firms. We believe that more experienced managers use corrupt ties to minimize barriers to enhance the innovative activity of their firms.

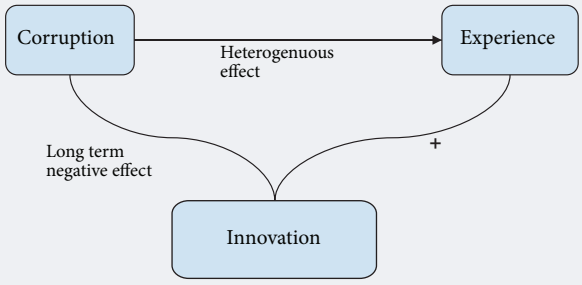
Based on the aforementioned ties between innovation and informal relations, we composed a theoretical research model which describes the links between corruption, manager's experience, and innovation (Figure 2). We consider measurable characteristics, such as years of experience as managers.

Development of Hypotheses

Years of Experience of Top-Level Management

Management plays a vital role in the decision-making, production, development, and continuity of innovative products. The development of any novel product and the role of top-level management (be it top-down or bottom-up approach) are inseparable (Kurniawan et al., 2016). In exploring the role of managers' work experience, ambidexterity, and performance, Mom et al. (2015) indicated that tenure is an antecedent of organizational and functional ambidexterity which in turn significantly predicts managerial behaviors as a result of their ability to shape cognitive processes,

Figure 2. **The Links between Corruption, Manager's Experience, and Innovation**



Source: authors.

skills, and motivations. Since tenure plays a role in shaping top-level managements' cognitive processes and behavior, it can be deduced that the longer a manager stays in office, the more he or she is accorded the due level of respect and fear (in certain scenarios).

The CEO's experience has a non-linear constraining effect on R&D investment (Yin et al., 2019). However, the experience may be different and the effect it has is also different. Researchers have argued that the age of top managers has a significant impact on their desire to innovate. Researchers have asserted that old managers are risk averse and are content (they have reach their peaks) with their achievements. Older managers have been socialized into accepting prevailing organizational conditions and routines and have greater psychological commitment to them; hence, they will be less willing to commit to changing them. Years of experience cannot directly be linked to the age of the executive manager (Huber et al., 1993). New managers are more likely to adopt new ways of doing things than managers who have been in the position for a very long period of time (Hambrick, Mason, 1984). The administrative processes are well understood by the managers who have been in the position for a long period of time (Kearney et al., 2000).

Such managers create networks for administrative matters (Lau, 2011). Therefore, we believe that with the growth of experience, managerial corruption declines and we formulate the hypothesis:

H1. The years of experience of top managers positively impact innovation activities and negatively impact corruption.

The issue of corruption has been a challenge for centuries and curbing it is of great importance to numerous governments and interest groups. Corruption is known to negatively influence socioeconomic development (Xiao et al., 2018).

With respect to innovative activities, studies by Anokhin and Schulze (2009) reveal the following: (i) corruption (which is also public power or authority abuse) for private benefit gravely affects the scale of the rewards from entrepreneurship and innovation; (ii) in corrupt environments, agency and transaction costs as well as other consequences of corruption potentially limit the scale and scope of economic activity. The result of corruption, according to literature and empirical evidence, is the stifling of innovation. In developed countries, corruption degrades the quality of institutions and negatively affects the development of startups (Woodside et al., 2016). Poor quality institutions do not stimulate innovation (Fischer, Tello-Gamarra, 2017; Mrad, Bouaziz, 2018).

Corruption is most in-demand in countries with economies in transition, which are characterized by the presence of weak institutions, which provokes increased transaction costs for businesses. In such circumstances, it is more profitable for an entrepreneur to develop a business with a bribe, creating a "new normal business environment" and introduce new innovative products to the market that can overcome bureaucratic obstacles (Krammer, 2019). Thus, corruption in developing countries is seen not as evil, but as "wheel grease" (Barasa, 2018; Riaz, Cantner, 2019), however the long-term effect is negative on the economy.

In Russia, research indicates that the public procurement sector faces issues of corruption due to the anti-corruption focus of the procurement legislation, which deprives governmental officials of the right to make decisions based on technical and economic reasoning (Sirotkina, Pavlovskaya, 2018). Nitsevich et al. (2018) also assert that despite a renewal in Russia, corruption has blossomed due to officials not being able to manage budgetary funds except for state property, numerous other legislative and social institutions. Corruption has therefore managed to create gargantuan distortions in the system of governance and functioning of state institutions. This in turn influences how business is done in the private sector as well. Thus with the above premise, we posit the following hypothesis:

H2. Managers with increased experience and so-called corruption competencies have an effect on innovation.

Data

The Enterprise Surveys (ES) conduct regular firm-level surveys in developing and emerging economies with the main aim of developing reliable and comparable datasets on various aspects of firm behavior and performance in those countries. The Enterprise Surveys (ES) are an ongoing World Bank project in collecting both objective data based on firms' experiences and enterprises' perception of the environment in which they operate. The studies are implemented using firm-level surveys and over the last 10 years have evolved into a mature product that since 2005 uses a standardized methodology of five implementations, sampling, and quality control in most client-countries of the World Bank. The Enterprise Surveys

currently cover over 130,000 firms in 125 countries, of which 107 have been surveyed following the standard methodology.

The data of variables for this research comes from the World Bank's Enterprise Survey 2019.[3] The World Bank interviewed a representative sample of the private sector composed of 4,220 business establishments from November 2018 through March 2020 across all cities in Russia. It covers several topics of the business environment as well as performance measures for each firm. The majority of the firms interviewed were small and medium scale companies. A total of 89.8% of the data is on SMEs in Russia distributed across a broad range of industries in both the manufacturing and service sectors. The World Bank categorizes business sizes as such: small (5–19 employees) and medium-sized (20–99 employees).

Methodology

The logit model is going to be used in estimating the results of the model. This is because the dependent variable is dichotomous, this means it takes the form Y [1, 0]. Using the ordinary least squares (OLS) method does not show the real effect of the model. We need to transform the dichotomous Y into a continuous variable Y′ œ (– ∞, ∞), so we need a link function F(Y) that takes a dichotomous Y and gives us a continuous, real-valued Y′. This link is the logit link. With the intention of improving the interpretability of the regression coefficients, we use marginal effects. The marginal effect is a measure of the instantaneous effect that a change in a particular explanatory variable has on the predicted probability of the dependent variable, when the other covariates are kept fixed. The dependent variable is modeled as follows:

$$y = E(y/x) + \varepsilon, \quad (1)$$

where E(y/x) is the conditional mean function, x is the vector of explanatory variables and ε is the error term. The conditional mean function is given by:

$$E(y/x) = F(\beta' x), \quad (2)$$

where F denotes a cumulative distribution function and denotes the parameters. Therefore,

$$Pr\,(y = 1) = F'\,(\beta' x) \quad (3)$$

Marginal effects are obtained by computing the derivative of the conditional mean function with respect to given by:

$$\frac{\delta E(y/x)}{\delta x} = f'(\beta' x)\beta, \quad (4)$$

where f (.) is the density function that corresponds to the cumulative function F(.).

In this study, where all the variables are categorical (mostly binary), we would report the difference between the estimated probability if the variable being equal to 1 and the estimated probability if the variable being equal to 0. The marginal effects are nonlinear functions of the parameter estimates and levels of the explanatory variables. To explain the results, we use the marginal effect estimates.

There are potential endogeneity issues associated with the estimation of the model. First, there might be an omitted variable that affects both a manager's experience and the nature of the firm, including its propensity to innovate. Second, there might be reverse causality between viewing corruption as an obstacle and the propensity to innovate: more innovative firms might view corruption as a bigger obstacle to their business than a less innovative firms. In other words, innovation might prompt various answers to this corruption as an obstacle question rather than the other way around. Given the cross-sectional nature of the dataset, we attempt to mitigate the endogeneity problem through the inclusion of regional fixed effects and control with firm size.

After estimating the first model, we apply the Johnson-Neyman interval to identify where the simple slopes are significant in the context of our interaction model. The Johnson-Neyman interval provides the two values of the moderator at which the slope of the predictor goes from non-significant to significant. This interval informs the formation of dummies of managers' years of experience. With this in mind, we can predict whether the experience of a top manager triggers corruption and how this influences a manager's propensity to innovate.

Dependent Variables

Innovation is the variable of interest for our analysis. In this survey there were four (4) items that addressed the subject of innovation, considering "new" as products, services, processes, practices, and methods that are new to the firm but not necessarily new to the market or other firms. Further, said innovations could have been originally developed by other firms. These prompts asked respondents to indicate (yes or no) about whether they introduced new products or services in the last three years.

The options are:

(i) "Has this establishment introduced new or significantly improved products or services?"

(ii) "Has this establishment introduced any new or significantly improved methods for the production

[3] https://microdata.worldbank.org/index.php/catalog/3561/pdf-documentation, accessed 19.10.2021.

or supply of products or services, organizational or management practices or structures?"

(iii) "Provide technology training for staff"

(iv) "Add new features to existing products or services" [4]

Xie et al. (2018) states that there are two kinds of activities that represent the two categories of technological innovation, namely, product and process innovation. Following (Xie et al., 2018; Cuijpers et al., 2011), we use item (i) as the dependent variable. Porter (1983, p. 22) provides a summary of technological innovation: "*Initially product design is fluid, and substantial product variety is present. Product innovation is the dominant mode of innovation and aims primarily at improving product performance. Successive product innovations ultimately yield a 'dominant design' where the optimal product configuration is reached.*"

Independent Variables

Years of experience of an executive manager: The prompt asked respondents "How many years of experience working in this sector does the top manager have?". The response ranges from 0-60 years.

Corruption: This subject is a very sensitive one, therefore questions that relate directly to the firm's possibly corrupt activities were less responded to, but we found a way to assess corruption even though a lot of respondents refused to answer the question. Prompts included the following: *"informal payments to public officials to 'get things done' with regard to customs, taxes, licenses, regulations, services etc. On average, what percentage of total annual sales or estimated total annual value, do establishments like this one pay in informal payments or gifts to public officials for this purpose?"*

There are certain factors that are important in the analysis of firms and innovation, and so we use these factors to control the outcome of the model. The control factors used for this research include firm size, labor regulations, firm age, R&D investment, financial access, and government subsidies. To be able to capture the regional effect, we included the GRP of Russian regions.

Results

The table below (Table 1) shows the results of the control variables' effect on product innovation. The results are in line with the literature, where education, firm size, and investment all demonstrate a higher likelihood of influencing firm innovation, but we see a surprising twist with competition, which is negatively impacts innovation. This can be attributed to a lack of competition. Aghion et al. (2009) state that "competition should have a negative (short-run) "Schumpeterian effect" on laggard firms' innovation incentives in unleveled sectors: increased competition reduces the post-innovation rents of laggard firms and thus their incentive to catch up with the leader." This implies that, in an unleveled sector, the leader gets the whole market and earns a monopoly rent. It is plausible that given that the companies analyzed are all SMEs with no active competition, this makes it easier for top companies to monopolize the market.

Firm size is positive but not significant. Regions of Russia show different effects upon innovation as we can see from Table 1, therefore, we cannot draw an earlier conclusion for this. The differences in OLS and the logit estimate are clearly visible as there is an improvement in the results of the estimates.

Table 2 below shows the logit model and its marginal effects, Model 1 comprises the top managers' experience and the control variables. The results show the same results for the control variable and show the positive effect of managers' experience with innovation, with a marginal effect of 0.03, this proves Hypothesis 1. In Model 2 we used the control variables and include managers' experience and corruption, we realized that with the inclusion of the corruption variable, the results remain the same for the managers' experience with corruption having a marginal effect of 0.25 with mild significance level. The interesting twist again is that competition becomes insignificant after the introduction of corruption in Model 2. Corruption always depends on power. This may be market power, for instance, when a purchasing agent for a monopoly over-invoices his transactions and the lack of yardstick comparison disguises his corruption. In Model 2 we also identified the mild effect of corruption upon managers' experience.

In Model 3 we model the interaction between managers' experience and corruption. The results show some form of interaction, this interaction is only negatively significant for corruption but not managers' experience. As the diagram below depicts, the crossing of the lines shows the different kinds (heterogeneous) of interactions that exist between experience and corruption. To highlight the effect, we need further testing like the Johnson-Neyman Interval to help us know at what level of experience does corruption become more effective.

After applying the Johnson-Neyman interval, Table 3 shows that when the years of experience of the top manager increases, the manager's interaction with corruption is significant. The interval shows that when experience is inside the interval [–2.42, 14.15], the slope of corruption is $p < 0.05$. This means the interaction of corruption and manager experience begins even before the manager takes on the leading role. Corruption is evident when the years of experi-

[4] The full version of the questionnaire contains another two questions that were exempted from the Russian list of interview questions, i.e. questions (v) "Take measures to reduce production cost" and (vi) "Take actions to improve production flexibility".

Table 1. **Estimates of the Control Variables**

Variable	Estimations			
	OLS	Logit	Marginal Effect	Odd Ratio
Education	0.002* (0.001)	0.013 (0.006)	0.01264	1.01
Investment	0.001* (0.000)	0.007* (0.003)	0.00656	1.01
Competition	–0.054* (0.025)	–0.565* (0.253)	–0.5645	0.57
Firm Size	0.010 (0.022)	0.104 (0.206)	0.104	1.11
Volga	–0.143*** (0.039)	–2.374** (0.743)	–2.374	0.09
Northwest	0.016 (0.038)	0.080 (0.314)	0.08047	1.08
Siberian	–0.044 (0.039)	–0.397 (0.373)	–0.3972	0.67
Ural	–0.080* (0.036)	–0.806* (0.376)	–0.806	0.45
Southern	0.084* (0.039)	0.514. (0.302)	0.5143	1.67
Far Eastern	–0.041 (0.036)	–0.368 (0.341)	–0.3678	0.69
Constant	0.141*** (0.040)	–1.843*** (0.370)	–	0.16
Observation	922	922	–	–
AIC	–	681.3	–	–
R^2 Tjur	–	0.058	–	–
R-Squared	0.05627	–	–	–
F Statistic	5.438*** *(df= 10; 912)*	–	–	–

Note: *p<0.1; **p<0.05; ***p<0.01.

Summary of fitted Logit regression models: coefficient estimates (with Wald standard errors in parentheses), the number of estimated parameters and log-likelihood. Summary of the average marginal effect of each of the models is also reported.

Source: authors.

ence of the top manager increases. From our analysis, the manager possesses these qualities before taking office as executive manager until the 14th year. This can be attributed to networking, which is inevitable in business. Recent research finds that differences in individual creativity and intelligence matter far less for innovation than connections and networks. This network therefore enforces corruption, the exchange of ideas, and also helps beat the time-consuming bureaucratic processes, which facilitate the innovation process. The immediate effect of corruption is good for the business and the leaders but the long-term effect is negative as the interval shows.

In Table 4, we continue to find that managers' propensity to innovate increases with years of experience. We analyzed top managers from 0-14 and the result shows a negative but insignificant effect of experience on innovation, but analyzing the data from 14 years and above experience shows a strong effect of top managers' experience on innovation and we also see that corruption becomes insignificant with increase in experience. All the models show an increasing effect of managers' propensity to innovate with experience. Managers with less experience are less innovative as compared to managers with many years of experience. This can also be linked directly with networking and corruption as well as the specifics of the process of innovation implementation.

Discussion

The results have shown that managers' propensity to innovate depends on the experiences they acquire along the way and that corruption also plays its part in helping them outsmart the bureaucratic processes. The characteristics of the manager in the innovation process matters most in achieving the best possible results. Inexperienced managers might have the needed motivation to innovate because they are young and very prepared for the risk, but to be successful, they need to learn through experiences and be able to beat the bureaucratic process especially in developing countries. Innovation is the pillar of every great company; growth cannot occur without implementation of innovative strategies and actions and this process takes a long time. We realized that there is an increasing trend with experience, as the top manager gains more experience, their propensity to innovate also increases. This can be noted by an *increase in confidence* — there is a common saying "Experience is the most efficient teacher of all things." A lot of managers learn on the job before obtaining the needed training which the *Harvard Business Review* refers to as "Trial and error", the job serves as a training ground for the managers of most SMEs. The time spent on the job exposes the leaders to the things which cannot be easily acquired in the classroom, time increases the confidence of the leaders and exposes them to different leaders who can be mentors for them. As they understand the mechanism of their trade, they become more confident in taking the necessary risks. In other words, the confidence of the top manager increases their appetite for growth and thereby increases their risk appetite also. This period also exposes them to the right people and networks which facilitates corruption and increases the speed of the innovation process. Corruption in SMEs especially in Russia is inevitable because of the bureaucratic processes,

Table 2. **Logit Mode and Marginal Effects**

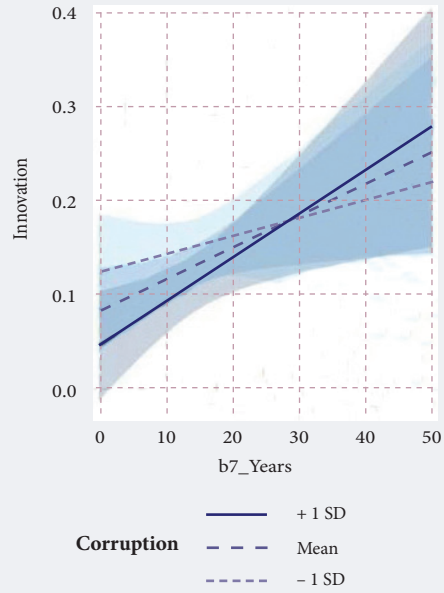
Variable	Model 1			Model 2			Model 3		
	Est.	*Marginal Effect*	*P–value*	*Est.*	*Marginal Effect*	*P–value*	*Est.*	*Marginal Effect*	*P–value*
(Intercept)	–2.34*** (0.42)	–	<0.00	–2.08*** (0.43)	–	<0.001	–2.18*** (0.39)	–	<0.001
Education	0.01* (0.01)	0.01	0.03	0.01* (0.01)	0.02	0.024	0.02* (0.01)	0.02	0.012
Investment	0.01* (0.00)	0.01	0.02	0.01* (0.00)	0.01	0.012	0.01*** (0.00)	0.01	0.001
Competition	–0.58* (0.26)	–0.58	0.02	–0.43 (0.26)	–0.43	0.095	–0.27 (0.25)	–0.27	0.284
Firm Size	0.04 (0.21)	0.03	0.86	0.08 (0.21)	0.08	0.692	0.05 (0.20)	0.05	0.798
Managers Experience	0.04** (0.01)	0.04	0.01	0.04** (0.01)	0.04	0.006	0.01 (0.02)	0.03	0.378
Corruption	–	–	–	–0.25* (0.10)	–0.25	0.012	–0.39* (0.19)	–0.21	0.042
M*C	–	–	–	–	–	–	0.01 (0.01)	0.01	0.173
Regional Fixed Effect	Yes	–	–	Yes	–	–	No	–	–
Observation	*923*	–	––	923	–	–	923	–	–
BIC	*734.40*	–	–	734.41	–	–	738.80	–	–
AIC	*676.47*	–	–	671.65	–	–	700.18	–	–
Pseudo–R^2 (McFadden)	*0.09*	–	–	0.09	–	–	0.04	–	–
Pseudo–R^2 (Cragg–Uhler)	*0.12*	–	–	0.13	–	–	0.06	–	–
χ^2	60.84, p = 0.00	–	–	67.66, p = 0.00	–	–	29.13, p = 0.00	–	–

Note: *p<0.1; **p<0.05; ***p<0.01.

Summary of fitted Logit regression models: coefficient estimates (with Wald standard errors in parentheses), the number of estimated parameters and log–likelihood. Summary of the average marginal effect of each of the models is also reported..

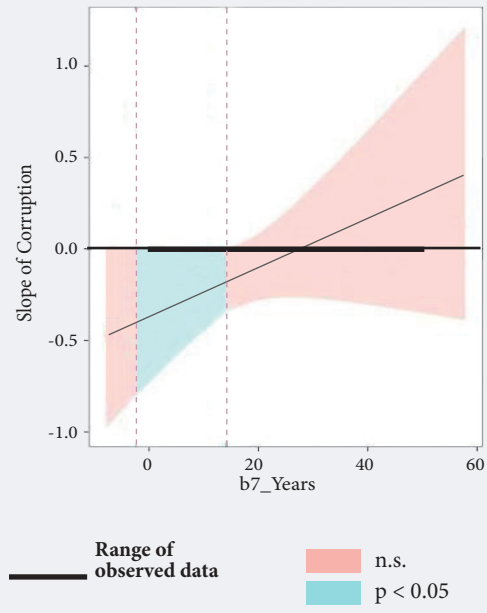
Source: authors.

Figure 3. **Slopes of Corruption**



Source: authors.

Figure 4. **Johnson-Neyman Plot**



Source: authors.

Table 3. **Johnson-Neyman Interval and Simple Slopes Analysis**

Parameter	Est.	S.E.	z val.	p
Slope of Corruption when b7_Years = 5.79233 (– 1 SD)	–0.29	0.14	–2.12	0.03
Slope of Corruption when b7_Years = 13.64139 (Mean)	–0.18	0.09	–2.01	0.04
Slope of Corruption when b7_Years = 21.49044 (+ 1 SD)	–0.08	0.10	–0.79	0.43

Note: When b7_Years is INSIDE the interval [–2.42, 14.15], the Slope of Corruption is $p < 0.05$. The range of observed values of b7_Years is [0.00, 50.00].

Source: authors.

which are time-consuming, therefore managers find it safer to pay their way through the process.

In order to change the current situation, the implementation of the following measures seems relevant:

1. *Restructuring of institutions to accelerate business processes.* Governments of transitional and emerging economies need institutional changes to meet the growing demands of startups and SMEs. Especially the easing of regulations for minority groups and people with less opportunities to be on the same playing field. An environment must be created that promotes competition and equal opportunities.
2. *Patent application process needs to be shortened.* The long waiting time for patent application prompts leaders to use dubious means to facilitate the process.
3. *Contactless System.* Using a contactless system in the application process can also ensure a decrease in corruption and reduce bureaucratic processes. Such a system will reduce discrimination and reduce the time it takes businesses to get things done. Digital payments have been proven to reduce corrupt behaviors (Shrivastava, Bhattacherjee, 2015) and increase transparency in financial transactions (Corojan, Criado, 2012). The more cashless the transitioning and emerging economies, the less rampant corruption will be. Digitalization enables financial transparency by improving business record keeping and lowering transaction costs.

Table 4. **Top-Level Management's Propensity to Innovate**

	Model 1 (Exp.< 14)	Marginal effect	Model 2 (Exp. ≥ 14)	Marginal effect
Manager Experience	–0.04 (0.04)	–0.03887	0.09*** (0.02)	0.0892
Corruption	–0.32* (0.16)	–0.3211	–0.22 (0.13)	–0.221
Control	Yes	–	Yes	–
Fixed.E (region)	Yes	–	Yes	–
AIC	325.25	–	326.74	–
BIC	379.64	–	379.08	–
Pseudo–R^2	0.20	–	0.21	–
χ^2	51.86, p = 0.00	–	52.37, p = 0.00	–
Num. obs.	485	–	414	–

Note: *p<0.1; **p<0.05; ***p<0.01.

Summary of fitted Logit regression models: coefficient estimates (with Wald standard errors in parentheses), the number of estimated parameters and log-likelihood, with regional fixed effect and control variables controlled.

Source: authors.

Conclusion

This research used the Russian enterprise survey 2019 data from the World Bank to explore top managers' propensity to innovate through experience and corruption. Our study revealed that as experience increases, so does the manager's propensity to innovate. We found that corruption increases with top managers' years of experience as this happens due to the high level of bureaucracy and weak institutions which causes top leaders to lose time and money. So to avoid losing time and money, they adapt to cheating to make the process faster. Osburg's (2018) findings on China back this paper's conclusions: it indicated that elite entrepreneur networks contribute corruption because these business owners are likely to obtain some level of protection which benefits and enhances their business success. The researchers also linked this to certain unwritten rules of bribery and corruption which become the norm for the advancement of circumventing business best practices and laws.

With respect to the theoretical contributions of the study, our findings contribute to the body of knowledge on the factors that influence innovation, particularly within the Russian research context. Also, our study provides practical contributions in the area of implementing a logit model which delivers an improvement in the results of the estimates.

Just like every evolving research field, for the purpose of future studies, we recommend extending this study to CIS (Commonwealth of Independent States), i.e. former Soviet, countries due to the fact that they share similar cultural and business characteristics with Russia.

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Financial Inclusion as Enabler for Innovation in Banking

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Abstract

Using evidence from Spain, this study assesses the readiness of the banking sector of the EU to introduce technological and social innovations to implement the European policy of financial inclusivity. Despite the evident benefits for banks in terms of enhancing legitimacy and improving consumer knowledge and loyalty, mostly banks at present merely comply with the formal aspects of financial inclusion regulation, but are not going further in terms of technical or social innovation, using compliance to avoid the 'stick' of regulation. In contrast, a review of the banks' own corporate social responsibility strategies shows a higher level of commitment and innovation in terms of financial inclusion. Based on the analysis of institutional factors that determine the involvement of banks in the inclusivity policy, recommendations are proposed for adjusting development strategies in order to combine the efforts of the public and private sectors in the provision of public services.

Keywords: financial inclusion; knowledge-intensive services; public policy; innovation; new technologies; strategies; digitalization.

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Introduction

The present-day banking sector is under pressure from two main factors: on the one hand, it must comply with the legal requirements on financial inclusion (equal access to services for all social groups), while on the other, make sure profits keep growing. To maneuver between these objectives, banks implement complex strategies taking into account many various factors.

In the European Union (EU), universal access to basic payment services, including bank accounts, is seen as a social cohesion condition.[1] Private banks must provide a minimum set of services to all Europeans, regardless of citizenship and place of residence, to overcome the financial exclusion of vulnerable social groups (Gloukoviezoff, 2007). Such services provided on customers' request, without making it conditional on accepting other offers, include basic payment accounts (BPA).

The relevant literature is focused on the relationship between increasing profits and the effectiveness of corporate social responsibility (CSR) strategies. However, specific features of private companies' provision of public benefits have not yet been described in detail (McWilliams, Siegel, 2011). The purpose of this paper is to assess the development of social innovations to make BPA transparent and available, and increase their contribution to the implementation of the European financial inclusion policy.

Literature Review

The European Commission's priorities in promoting innovation-based growth of financial markets include increasing the availability of services to reduce social stratification (De Serres, Roux, 2006). In the current context, the inability to use bank payment tools makes it impossible to conduct almost any transaction (Storm, 2018; Sawyer, 2014). While the demand for cash to a store of wealth has grown (Goodhart, Ashworth, 2020; Jobst, Stix, 2017), for making payments it is used increasingly rarely, at least in developed countries (Guttmann et al., 2021; Arango-Arango, Suarez-Arisa, 2020). For example, in Sweden most payments are made using bank cards, electronic wallets, etc. (Engert et al., 2019). The list of everyday transactions for which the use of cash is prohibited and intermediaries are required in the form of official financial institutions, is expanding. A similar trend exists in all European countries (Lazarus, Luzzi, 2015; Lazarus, 2017).

The availability and security of financial products is becoming a key factor in improving the quality of life (Kear, 2013; Storm, 2018). Financial inclusion implies the productive use of services by all social groups (Anderloni, Carluccio, 2007). That said, low-income clients may be discouraged by high service fees for using bank accounts (Cartwright, 2015; Mendoza, 2011).

Approaches to Tackling Financial Exclusion

The phenomenon of financial exclusion is primarily addressed by public and "protective" organizations - credit unions and savings banks, which traditionally rely on the equal treatment of all clients ("relational banking") (Delgado et al., 2007; Culpepper, 2002). However, the 2008 economic crisis has significantly affected banks' activities, leading to a reduction in the number of branches . The lower interest rates led to a decrease in profit margins. Barriers have arisen hindering "cross-subsidizing" practices, when revenues from profitable business segments offset losses incurred elsewhere (Froud et al., 2017; Marron, 2013). The need to improve operational performance became more urgent. A new business model has emerged, "flight to quality", enhancing consumer value through customer segmentation (Froud et al., 2017; Molyneux, 2007). However, the supply of cheap banking services has declined, with low-income customer segments finding themselves with a limited ability to use them (Ayadi et al., 2010). The proliferation of digital technologies combined with insufficient user support lead to those without the skills needed to use them being cut off from banking services altogether (Clark, Myers, 2018; Gloukoviezoff, 2007).

This context prompted EU regulators to take steps to protect vulnerable consumers, including introducing basic payment services (European Commission, 2011a). Sweden, Finland, Denmark, Belgium, and France acted proactively, by enshrining the right to a personal bank account in the law, while the Netherlands prohibited refusing applications to open one (Gómez-Barroso, Marbán-Flores, 2013). European legislation guarantees the right to open a BPA regardless of the clients' employment status, income, credit history, or bankruptcy. Banks are expected to educate the most vulnerable customer groups on responsible financial management. The document aims to support a new social policy which allows for government intervention in the provision of financial services in the event of market failures

[1] European Commission Regulation 2014/92/EU от 23.07.2014. https://www.wsbi-esbg.org/Positions/Payments/Payment_Accounts_Directive, accessed on 12.02.2022.

with major social consequences (Gómez-Barroso, Marbán-Flores, 2013). This can negatively affect banks' performance, since they must choose between improving the efficiency of their operations or meeting their social responsibilities (Maudos, De Guevara, 2007). The question arises of which non-commercial motives banks may be guided by in providing basic services, and how their partnership with the state and application of digital technologies contribute to improving social welfare (Adeel et al., 2013).

Financial Inclusion

Non-profit strategies play an important role in managing organizations' institutional and social context (Bonardi et al., 2006). They imply adhering to CSR principles and a focus on public good (Mellahi et al., 2016; Anguinis, Glavas, 2012). Re-orienting business models to create added value for stakeholders, and shifting the focus to social responsibilities have a number of positive effects such as improved reputation, increased consumer loyalty, better relations with stakeholders, easier access to funding, and other important resources (Mellahi et al., 2016; Surroca et al., 2010; Anguinis, Glavas, 2012).

Systemic economic risks arising from banks' activities lead to the introduction of special requirements for their legitimacy (Ülgen, 2018, 2021; Culpepper, 2002). Most banks use public assets (people's savings, etc.). Consequently, they need to generate public good, in particular provide financial inclusion (Roa Garcia, 2016; Morgan, Pontines, 2014; Cull et al., 2021). However, the extent to which banking services are "social" may differ from other public benefits, such as security (Ozili 2020; Gupte et al., 2012). Banks are expected to cover the cost of providing free or inclusive services as part of their business costs, which to some extent may be subsidized by the government (Ozili, 2020). An inclusive approach to providing basic financial services looks like a promising area for joint public-private projects (Ülgen, 2021).

The issue of financial exclusion in developing countries is most often addressed through microfinance, often with government support (Adeel et al., 2013; Hardy et al., 2010). In developed countries, tools to reduce "poverty premium" are applied for this purpose, which arises from the reduced use of banking services all the way to completely abandoning them ("underbanking" and "unbanking")[2] and from digital isolation.

The above challenges are exacerbated by the proliferation of cashless payments. Digital technologies reduce the cost of basic financial services and improve service quality, but users who do not have the necessary skills face problems (Bielefield et al., 2021). The European Commission expects banks to address the issues with which the market cannot cope.

Given the internal and external incentives for banks to follow the CSR principles, questions arise about whether they simply comply with letter of the law, or try to find innovative approaches to promote an inclusive financial services market, and if so, what is their contribution in this area?

Research on this topic remains scarce, especially regarding customer experience. It is assumed that banks will only benefit from strengthening their own legitimacy, increasing awareness, and strengthening customer loyalty. Therefore filling the existing knowledge gap is critical for banks and regulators alike.

Design and Methodology of the Study

European legislation on payment accounts implies adapting to national standards,[3] so relevant studies must be carried out at the national level. This will eliminate distortions in the conclusions on the implementation of relevant strategies due to country-specific features.

Spain is of interest as an object of study for several reasons. The country's banking sector is a leader in CSR and sustainable development. Five banks are in the top ten in the European Dow Jones Sustainability Index ranking.[4] At the same time, there is the "underbanking" trend among low-income population groups, despite the high total share of account holders. The availability of financial services for this group is comparable to that for the general population, but its members are much less likely to use payment tools such as debit cards due to high service fees.[5] Mandatory criteria for information transparency regarding BPA have been introduced for various communication channels. Special conditions are offered for vulnerable customers,[6] including free BPA.

[2] In the EU context, 'unbanked' refers generally to "people with no bank at all". 'Underbanked' or 'marginal banked' refers to "people with a deposit account that has no electronic payment facilities and no payment card or cheque book. It can also be people who do have these facilities but make little or no use of them" (Anderloni et al., 2008).

[3] In the case of Spain, according to the Royal Decree 19/2017 of 24.11.2017. https://www.boe.es/buscar/doc.php?id=BOE-A-2017-13644, accessed on 22.10.2021.

[4] https://portal.csa.spglobal.com/survey/documents/DJSIComponentsEurope_2020_.pdf, accessed on 22.10.2021.

[5] https://www2.cruzroja.es/-/boletin-n-11-sobre-vulnerabilidad-social, accessed on 12.11.2020.

[6] Regulation ECE/228/2019 от 28.02.2019. https://www.boe.es/buscar/pdf/2019/BOE-A-2019-3113-consolidado.pdf, accessed on 14.06.2021.

Table 1. **Requirements for Basic Payment Accounts**

Conditions	RD-law 19/2017	Directive 2014/92 / EU
General duties	- All banking entities shall offer basic payment accounts. - All advertising, information and contractual documentation shall be identified with the name "basic payment account."	- Enough credit institutions shall offer BPA to guarantee that all consumers have access to them, avoid any type of discrimination, and guarantee free competition. - Non-discrimination or stigmatization regarding the products appearance or the 'specialization' of certain entities.
Beneficiaries	-EU residents, including people without a fixed address, asylum seekers and people without residence permission, whose expulsion is impossible for legal or factual reasons.	
General fees	-Cost according to entity-client negotiation, with a reasonable maximum established by the Ministry of Economic Affairs (Order ECE/228/2019, 28 February): 3€ per month covering a maximum of 120 transactions per year. -Regulation can determine more advantageous conditions for vulnerable consumers (Royal Decree 164/2019, 22 March): Free for vulnerable population. - Entities shall offer information on characteristics, fees or conditions of BPA through any distribution channel.	-Free or reasonable cost. - Advantageous conditions for vulnerable consumers. -Reasonable fees for non-compliance. - Limit maximum amount and duration of overdrafts (if allowed). -Maximum transparency on fees.
Additional fees	-Additional costs may not exceed the average commissions applied by each entity.	- Guarantee essential additional services according to uses of the country, at a reasonable cost.
Personnel training		- Adequate training of the personnel of the banking entities. - Avoid possible conflicts of interest having a negative impact on clients.
Denial to open BPA	- Holders of another account, unless the entity has unilaterally decided to close it. -Denial for failure to provide the information required to assess risks of money laundering or anti-terrorism.	- Holders of an equivalent active payment account in the same member state. - Cases of refusal limited to non-compliance with the regulations on money laundering or anti-terrorism.
Covered services	-Unlimited operations regarding management and payment services, and within the EU.	- Deposits, cash withdrawals, payment card, various payments (without limit), direct debits, debits and transfers (regulated minimum), online banking services. -Do not restrict to online services.
Contracting of additional products	-The contracting of other products or capital participations or similar will be compulsory only if it is unavoidable for all the clients of the entity. -The non-need to contract other products will be showed in the advertising information.	-Clear and understandable information on the right to open and use a BPA. -Adapted to vulnerable consumers. - Highlight the non-need to contract other products.
Promotion	- Ministry of Economic Affairs stablishes the measures to inform and advise credit institutions consumers, particularly the most vulnerable people.	-Education, advice and assistance for vulnerable consumers. -Financial and independent training provided by the credit institutions.
Source: own elaboration from the mentioned regulation.		

Table 1 compares the main requirements for national banks regarding BPA, with references to relevant European legislation.

We analyzed Spanish banks' BPA strategies in terms of minimum necessary versus excessive (going beyond the basic requirements) compliance with European and national rules. Possible signs of applying social or technological innovations were considered in such areas as meeting information provision requirements[7] (Table 2); information on the services and their costs,[8] free BPA[9] (Table 3); and customer support to open BPA[10] (Table 4). The use of additional criteria allowed us to determine whether sufficient support was provided to users.

Sample Selection

The objects for analysis were selected from the total of 199 organizations meeting the Bank of Spain's standards for offering a BPA. Annual reports available in national financial associations' databases were studied.[11] Since the BPA can be used to deposit savings and make payments, the amount of deposits was considered to be the best measure of this service's value. This criterion is preferred to other operations that were not included in the number of basic services guaranteed by law (e.g., the provision of loans). The amount of savings in BPAs is undisclosed. Based on the balance sheets, 15 leading banks were identified in terms of the amount of cus-

[7] Regulation ECE/228/2019, ст. 8.

[8] Regulation ECE/228/2019, ст. 4.

[9] Royal Decree 164/2019 (see above).

[10] Including other services in addition to the minimum set defined by Art. 4 of Regulation ECE/228/2019, and the list of the most common payment account services published by the Bank of Spain (Royal Decree 19/2017, art. 15, see above).

[11] Among them are the Spanish Banking Association, the Spanish Confederation of Savings Banks, and the National Union of Credit Cooperatives.

Table 2. **Duty of Information Indicators (compliance).**

Code	Review question (answer — yes / no)
Website info	Is there information on BPA on the entity's website?
General conditions	Is it specified who can contract the BPA and the conditions to be met?
No-obligation purchasing additional services	Is it indicated that it is not mandatory to contract other services?
Opening procedure and documentation	Does it include information on the opening procedure and the documentation to be provided?
Dispute resolution system	Is the alternative dispute or litigation resolution system mentioned?

Source: own elaboration.

Table 3. **Services and Fees Indicators (compliance)**

Code	Review question (answer — yes / no)
Maximum fee	Does the entity charge the maximum fee for the services described in article 4.2?
Extra fees	Does the entity charge fees when exceeding 120 operations per year (art. 4.2)?
Fees reporting	Does the entity quarterly report to the BdE regarding fees and/or average costs of BPA?
Cash withdrawals' fees reporting	Does the entity report if it charges fees for cash withdrawals from ATMs?
No-cost requirement disclosure	Does the entity disclosure that BPA have not cost for people in situations of vulnerability / risk of financial exclusion?

Source: own elaboration.

Table 4. **Assistance and Additional Services Indicators (over-compliance)**

Code	Review question (answer — yes / no)
Credit card	Is it possible to contract a credit card associated with the BPA?
Credit cash on ATM	Does the BPA allow the withdrawal of cash on credit at ATMs?
Arranged overdrafts	Does the BPA allow arranged overdrafts?
Unarranged overdrafts	Does the BPA allow unarranged overdrafts?
Foreign currency	Does the BPA allow transactions in foreign currency or currency exchange?
Alert service	Is there an alert service (SMS, email) associated with the BPA?
Check negotiation	Does the entity provide check negotiation and clearing services for BPA?
Check return	Does the entity provide return of cheques for BPA?

Source: own elaboration.

Table 5. **Top15 Volume of Deposits**

	Deposits (Millions €)	% Total
TOP15	1 190 691.20	88.6
Total credit institutions	1 343 678.48	100

Source: own elaboration

tomer deposits (Tables 5 and 6). The correlation between CSR and performance indicators strengthens as organizations become larger, more visible, and more transparent (Anguinis, Glavas, 2012).

To ensure the sample's homogeneity, two organizations were excluded from it.[12] Accordingly, 13 banks remained, which accounted for 85% of the total national savings deposits (1,144,903.10 million euros) based on data from 2018.

Financial Inclusion Policies

The inclusion policy status of the banks in the sample was assessed on the basis of their non-financial reports for 2019 and 2020.[13] Summary results are presented in Table 7. About half of the banks in the sample published formal financial inclusion commitments. The rest have outlined the relevant provisions in their "sustainable development matrices", but their priority remains low and they are not mentioned in the CSR strategies.

The strategy provides for digital, functional (for the disabled), and territorial (remote areas) accessibility. No special attention is paid to "unbanked" and "underbanked" people, or to low-income customers. Such services are mainly focused on lending (microloans, mortgage terms revision). However, certain globally operating banks offer, on the basis of technological and social innovations, tailored payment options for markets with a high level of financial exclusion.

References to the BPA are limited to a compliance declaration, but advisory user support and active promotion of the services in question are not part of the inclusion strategy. The most advanced initiatives have been developed by international banks for countries with a high level of financial exclusion. In particular, these include a scalable strategy based on a multi-product portfolio of low-cost innovative digital solutions. Big data mining is becoming increasingly important in the implementation of new social initiatives.

Data Collection

Data was collected at the end of 2019. At the first stage, information published on websites of the banks in the sample and of the Bank of Spain was analyzed. Banks were considered to be complying with the requirements if all the information provided in official documents was available on their web-

[12] ING Bank provides mainly online services, while our study focused on customer service at bank branches. Banca March targets the wealthy segment of individual users and corporate clients.

[13] Sometimes they are referred to as "sustainability reports". Must be presented according to Regulation 2014/95/EU of 10/22/2014 (https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32014L0095, accessed 19.12.2021) They are used by shareholders and other stakeholders who respond to CSR by favorably assessing the company and its services, which strengthens its reputation (Anguinis, Glavas, 2012).

Table 6. **TOP15 Credit Institutions**

EUR CODE	Name	Deposits (Millions €)
ES0049	Banco Santander	240 693.37
ES2100	CaixaBank	195 196.47
ES0182	BBVA	192 419.20
ES2038	Bankia	130 084.65
ES0081	Banco de Sabadell	106 907.37
ES0128	Bankinter	48 982.33
ES2103	Unicaja Banco	43 708.87
ES2080	Abanca Corporación	37 380.94
ES2095	Kutxabank	35 638.41
ES2085	Ibercaja Banco	35 493.37
ES1465	ING Bank	35 317.19
ES2048	Liberbank	30 828.58
ES3058	Cajamar Caja Rural	27 948.09
ES3035	Caja Laboral Popular	19 621.47
ES0061	Banca March	10 470.91
TOTAL DEPOSITS		1 190 691.20

Source: own elaboration.

Table 7. **Analysis of Financial Inclusion Policies (share of involved banks, %)**

Indicator	2019	2020
Financial inclusion strategy	53.85	53.85
• not just territorial inclusion	46.15	46.15
Address unbanking/underbanking	7.69	15.38
Services for low-income customers	15.38	30.77
Refers to the BPA	15.38	7.69
Refers to technological innovation in business	100.00	100.00

Source: own elaboration based on non-financial reporting.

sites. At the second stage, field research was carried out using the "mystery shopping" method, which is quite common, but still rarely applied in the banking sector (Wilson, 1998; Pinar et al., 2009; Tarantola et al., 2012; Kaffenberger, Sobol, 2017). One branch of each bank in the sample was visited in three cities: Madrid, Bilbao, and Valencia. The branches were randomly selected based on location in the lowest income areas.[14] A specially trained group of three "mystery shoppers" assessed how complete the information available on information stands and obtained from the branch staff was. To avoid distortions in data analysis, standardized criteria were applied. All bank websites were studied by the same expert. The survey results were aggregated, and the assessments were checked with the respondents (the "mystery shoppers").

Results and Discussion

Analysis of Open Source Data

Banks generally comply with the minimum requirements for informing customers about BPAs, clearly describe contract terms, and do not pressure customers into procuring additional products (Table 8). Only in a few cases was the displayed information incomplete. Most banks do not try to facilitate opening a BPA online. A little more than a third of the banks provide complete information about the regulations and the necessary documents. Banks seem to be trying to improve performance by targeting the "core customer segment" for CSR reasons (Mellahi et al., 2016) and BPA users do not belong in it. Low marketing activity in promoting BPAs compared to other services offered by the same banks seems to confirm this. This option is not even mentioned on the banks' websites among "other payment accounts".

Contrary to the opinions expressed by certain researchers (Brenkert, 1998; etc.), focusing marketing on vulnerable social groups produces varied effects for banks. In particular, it increases the number of BPA holders. One bank transferred all clients receiving social inclusion benefits to free accounts (presumably BPAs). An analysis of CSR reports published by the banks in the sample revealed only a few references to BPAs and only for vulnerable consumers. The fact that any client who meets the relevant requirements can open a such an account was not mentioned. Some banks offer enhanced options or lower prices for customers signing up online. However, many potential users of this service, especially elderly ones, may find themselves in digital isolation due to lack of access to mobile communications or the internet, and insufficient skills to confidently use it (Clark, Myers, 2018). To ensure their inclusion, banks will need to rethink the balance between their commercial interests and focusing on the public good.

All banks comply with the maximum monthly fee for BPAs, which is in line with the financial inclusion policy. Price regulation is considered justified only when there is a risk of financial exclusion.[15] However, most banks do charge extra for over-the-limit transactions.

[14] https://www.ine.es/experimental/atlas/exp_atlas_tab.htm, accessed 27.10.2019.

[15] http://www.ebf-fbe.eu/uploads/EBF%20Key%20Information%20Document%20on%20Bank%20Accounts.pdf, accessed 12.01.2021.

Table 8. **Analysis of compliance based on information disclosed on the webs**

Indicators	Compliant entities	
	number	%
Duty of information		
Website info	13	100
General Conditions	13	100
No-obligation purchasing additional services	13	100
Opening procedure and documentation	5	38.46
Dispute resolution system	3	23.08
Services and fees		
Maximum fee	13	100
Extra fees	9	69.23
Fees reporting	11	84.62
Cash withdrawals' fees reporting	13	100
No-cost conditions disclosure	13	100
Assistance and additional services		
Credit card	4	30.77
Credit cash on ATM	4	30.77
Arranged overdrafts	0	0.00
Unarranged overdrafts	4	30.77
Foreign currency	8	61.54
Alert service	11	84.62
Check negotiation	12	92.31
Check return	12	92.31

Source: own elaboration.

Banks do not apply any service fee innovations that could be considered part of a CSR strategy. For example, personalized pricing based on big data analytics (Yeoman, 2016) could better match rates to different customer profiles, within set limits. One bank offers financial solutions at reduced costs in developing countries based on new digital technologies. Only less than a third of the banks allow for linking credit cards to BPAs; the rest follow the rules and limit their offerings to debit or prepaid cards. Overdrafts (authorized or unauthorized) are usually not allowed, which indicates the desire to radically reduce the risks associated with opening BPAs. However, big data technologies help with personalized credit risk modeling and, accordingly, with risk management (Vassakis et al., 2018). Inclusion strategies implemented by international banks in countries with high levels of financial exclusion sometimes provide for lending and other "risky" services (one bank specializes in microloans).

Table 9. **Analysis of compliance based on visits and interviews**

Indicators	Compliant entities	
	number	%
Visibility of the information in the branch		
On the notice board	3	23.08
Specific brochure	7	53.85
Service accessibility		
Usefulness of the information and provision of contract forms	6	46.15
Quality perception of the branch assistance		
Known product/ adequate assistance	1	7.69

Source: own elaboration.

Field Research

During visits to bank branches the availability of BPA information[16] on bulletin boards and in booklets was assessed, along with the staff's willingness to communicate at least the minimum amount of necessary information and offer to open BPAs for customers. The aggregated results are presented in Table 9.

The staff did provide information to the "mystery shoppers", but due to their limited knowledge of BPAs, they constantly had to turn to corporate information resources for assistance. This state of affairs leads to most customers remaining unaware of this service, so demand for it stays low. Consumer organizations also remain sceptical, believing that only a small share of potential users actually open BPAs due to the low competitiveness of the product compared to other kinds of low-cost online accounts.[17] Unlike the European legislation, Spanish national regulations do not require training bank staff in the use of BPAs. There is no evidence that banks arrange such training themselves either. Still, some of the surveyed banks did improve their staff's skills in working with vulnerable client groups.

One incentive for the financial sector to offer inclusive services is legal pressure (Jeucken, Bouma, 1999; Matten, Moon, 2008). In an effort to pre-emptively respond to it, a major Spanish bank developed guidelines for serving vulnerable customers and preventing the accumulation of excessive debt.[18]

[16] Regulation ECE/228/2019 of 28.02.2019 (see above).

[17] https://www.ocu.org/dinero/cuenta-bancaria/noticias/cuentas-basicas, accessed 24.02.2021.

[18] https://www.santander.com/content/dam/santander-com/en/documentos/informe-anual/2020/ia-2020-annual-report-en.pdf, accessed 04.02.2022.

Thus, financial inclusion policies should not be limited to meeting the minimum mandatory requirements in order to avoid punishment. They can promote social innovation, which will help banks strengthen their reputation and institutional legitimacy, and develop human resources. Tools that can help one accomplish this include artificial intelligence (Yeoman, 2016), training sessions, and public-private partnerships to design digital solutions (Özili, 2020).

Conclusion

With regard to BPAs, Spanish banks seem to be limiting their efforts to comply with minimum requirements set by law. No innovation was discovered aimed either at improving free services (permitted and recommended by EU legislation) or personalizing BPA service fees. Despite the fact that the banking sector belongs in the knowledge-intensive services segment and therefore has significant innovation potential (Xiao, Zhao, 2012; Yip, Bocken, 2018), innovation in this area concerns processes rather than products (Gopalakrishnan, Damanpour, 2000). The analyzed reports revealed efforts to digitize services. BPAs require personalized attention to customers, which goes against the low-cost innovative digital services model. Since banks have no motivation to promote BPAs (Jeucken, Bouma, 1999), this service is offered only nominally due to legal pressure and forces not connected to the market.

On the contrary, banks actively use other financial inclusion formats in the framework of their CSR strategies (Jeucken, Bouma, 1999). This strengthens their reputation and institutional legitimacy, helps improve qualifications and motivation of the staff, and attracts resources for development. Targeting vulnerable customer groups in regions where the supply of banking services is insufficient, despite involving social obligations. has a fundamentally commercial motivation (Mulgan, 2006). That is the area where banks show the highest level of innovation activity.

This study offers a number of recommendations to improve financial inclusion policies, of which the BPA is a key tool. The goal is to make sure "no one is left without access to basic banking services".[19] The effectiveness of the strategy can be improved by deeply integrating BPAs into a bank's CSR model. Precise wording should be used to promote BPAs, the bank's website must be easy to search, and effective marketing campaigns should be implemented (Corrado, Corrado, 2015). Social innovation in financial inclusion can be promoted by training bank staff to work with vulnerable groups and using artificial intelligence technologies to advise customers. Given the downward trend in banks' profit margins, which is projected to continue for at least a few more years, cross-subsidizing (Froud et al., 2017) does not appear to be a compelling incentive to implement the above recommendations. Assessing BPAs' effects can present a difficult dilemma for bank management and government officials alike. Promoting public-private partnerships to provide basic services may be the solution.

Tax incentives and subsidies for providing particular banking services and developing technologies to serve vulnerable social groups could play an important role in co-creating customer value (Özili, 2020). Equally important is setting up working groups to share knowledge and experience in financial inclusion and related topics, involving representatives of non-profit organizations and social services.

The paper has certain limitations. Sufficient amounts of data for analysis were accumulated only from bank reports presented to the regulatory authorities. Difficulties arose in collecting data on the practical implementation of inclusion policies. The "mystery shopping" method is highly resource-intensive and the resulting sample was insufficient for effective application. For ethical reasons, interviews with bank employees were not recorded. The available statistics on the number of opened BPAs is limited for objective reasons. Due to these factors, it turned out to be impossible to properly use quantitative analytical methods, so the study was based on descriptive data. However, the "mystery shopping" method proved to be effective for analyzing other knowledge-intensive services.

Further research in other EU countries will allow one to more accurately assess the impact of BPA policies and their possible synergy with technological solutions and CSR strategies. This will lead to a better understanding of the overall dynamics of public-private partnerships in the provision of social benefits and ways to improve their effectiveness.

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[19] Paraphrasing the motto from the UN's 2030 agenda, "No one left beind". https://www.undp.org/sustainable-development-goals, accessed 11.02.2022.

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