FORESIGHT
AND STI GOVERNANCE
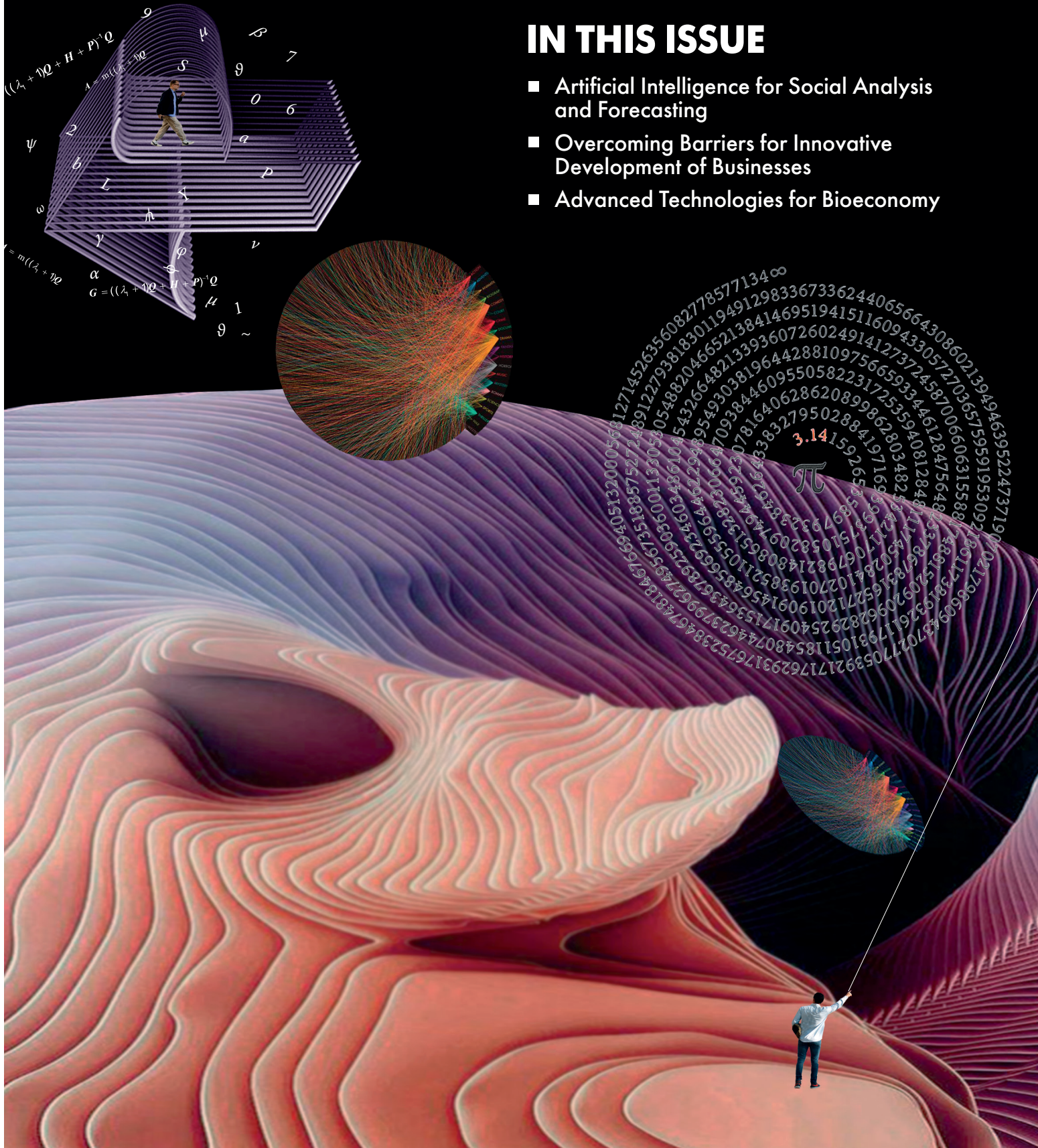
JOURNAL OF THE NATIONAL RESEARCH UNIVERSITY HIGHER SCHOOL OF ECONOMICS

IN THIS ISSUE

- Artificial Intelligence for Social Analysis and Forecasting
- Overcoming Barriers for Innovative Development of Businesses
- Advanced Technologies for Bioeconomy

ABOUT THE JOURNAL

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

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

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

and many others.

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

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

The journal is included into the 1st quartile (Q1) of the Scopus Cite Score Rank in the fields:
- **History and Philosophy of Science**
- **Social Sciences (miscellaneous)**

INDEXING AND ABSTRACTING

WEB OF SCIENCE™ CORE COLLECTION EMERGING SOURCES CITATION INDEX

SCOPUS™

中国知识基础设施工程 CNKI ● 中国知网

SHERPA/RoMEO

DRJI Directory of Research Journal Indexing

ERIHPLUS

ICI WORLD OF JOURNALS

RePEc

ProQuest

ULRICHSWEB™ GLOBAL SERIALS DIRECTORY

EBSCO

Academic Search Premier

GENAMICS™ JOURNALSEEK

ECONSTOR

eLIBRARY.RU

OAJI .net Open Academic Journals Index

DOAJ DIRECTORY OF OPEN ACCESS JOURNALS

CONTENTS
Vol. 18. No. 2

$$G = ((\lambda_1 + 1)Q + H + P)^{-1}Q$$

3.14

$$G = ((\lambda_1 + 1)Q + H + P)^{-1}Q \qquad A = m((\lambda_1 + 1)Q \qquad G = ((\lambda_1 + 1)Q + H + P)^{-1}Q$$

A Review of the Knowledge Worker as Prompt Engineer: How Good is AI at Societal Analysis and Future Predictions?

Klaus Solberg Söilen*

Professor, klasol@hh.se

Halmstad University, Kristian IV:s väg 3, 301 18 Halmstad, Sweden

Abstract

What is the literature on AI missing for prompting engineering so far, and how good are these services at Societal Analysis and Future Predictions? A literature review and laboratory tests were conducted using different AI services.

This study provides an extensive list of research gaps based on an analysis of existing literature. Furthermore, it demonstrates that AI with well-crafted prompts performs as well as or better than senior intelligence analysts in Societal Analysis and Future Predictions. The literature and analysis make it clear that the role of the prompter, to ensure reliability, must be divided into two parts: Prompt Engineering and Information Quality Control (IQC), which in this context is distinct from Prompt Answer Engineering. This study also proposes a working process in the form of a model for using AI in information or intelligence gathering. Additionally, it outlines the rationale for why top managers' salaries are likely to decrease as a result of these developments.

* This experimental paper was written by the author with the assistance of the generative AI service ChatGPT (https://www.chatgpt.com).

Introduction

Since ChatGPT's launch in November 2022, there have been significant changes in information and knowledge work. This study outlines these shifts, highlights challenges, and proposes new methodologies, frameworks, and models as suggested in the literature. It also puts forward a list of areas for future studies, all with the help of AI and accredited as such.

Various terms describe professionals working with information and knowledge. At the broad end *Knowledge Workers* possess specialized expertise in creating and using knowledge. *Information Workers* focus on processing and distributing information, relying heavily on technology. At the narrower end, *Intelligence Analysts* analyze and interpret data to support decision-making in different sectors. Similar professions include data analysts, financial analysts, and market researchers.

Healthcare providers and transportation workers are two examples of professions experiencing a rapid digital transformation. Professions not primarily concerned with information, such as manual laborers, service workers, skilled tradespeople, farmers, and security personnel, are becoming fewer.

It is no exaggeration to say that we are on the brink of *the third digital revolution*, characterized by the advent of personal computers, the proliferation of the Internet, and now the dawn of artificial intelligence (AI). Machines today efficiently sift through large datasets, extracting crucial information, and issuing alerts based on user-set parameters, thus addressing concerns. The professions that work more intensely with information, such as intelligence analysts, are most affected by these changes in AI. However, is there also a way that they work differently with AI than other broader groups of knowledge workers?

A divide has already emerged within the workforce regarding AI adoption. Employees skilled in using ChatGPT plugins effectively are contrasted with those still learning the basics, with the latter group risking obsolescence in the coming years. This divide is reminiscent of the one observed during the emergence of the first personal computers. Employee training in prompt engineering and related fields will be crucial to prevent the phasing out of entire professions. Much focus has been directed at lawyers as ChatGPT is good at finding and citing judicial texts, but the development affects everyone working with information. Artists and their professions face a crisis extending beyond replacement by AI, struggling with issues of identity and self-worth. And there is even now a growing nostalgia for human-made content as we move deeper into machine learning.

The new AI paradigm brings other problems, too. The 'Garbage In, Garbage Out' (GIGO) problem has become more dire. Organizations have largely turned to big data for their information needs, shifting their focus away from human intelligence (HUMINT) and the collecting of information from the front line in sales. Instead, decision-makers now tend to better trust the information given by AI and the large data providers like Gartner and Bombora. The problem is that they have less control over the data quality, leading to increased reliance on potentially irrelevant and, at worst, inaccurate information. Moreover, competitors are all buying the same data, which again leads to the same conclusions about the market among competitors.

State intelligence services, for their part, are adapting too, rapidly moving towards the vision of an Orwellian 'Total Intelligence Society', a vision of constant surveillance and the full collection of data footprints left behind by citizens domestically and internationally. As a counterreaction, advocacy groups are pushing for strict surveillance regulations to protect people's privacy. However, households, when pressured economically and when experiencing increased crime rates, often prioritize *security over privacy*.

In this study, we want to consider the state of research, identify the research gaps, and determine how good AI is at doing its job as a knowledge worker, and, more specifically, as an intelligence analyst and data scientist.

Launching cognitive pilots and developing scaling strategies requires collaboration between tech experts and business process owners (Davenport, Ronanki, 2018). However, current trends suggest that AI will even replace prompt engineers, capable of autonomously formulating and asking questions with clear direction and problem definition. In the future, starting a company might be as simple as asking AI to define market opportunities and an accompanying set of strategies, with AI creating prompts for all departments within the organization to achieve predetermined goals while robots handle production and distribution. This vision is no longer quite as utopian as previously anticipated.

Methodology

This paper uses a descriptive approach, providing an overview of AI developments over the past year. Twenty articles related to prompt engineering, all published in 2023 since ChatGPT's inception, were analyzed out of a randomly selected review of more than 40 articles from various disciplines and identified using Google Scholar. Information about the concerns and challenges faced by professionals in the field was extracted using AskyourPDF, a plugin. The material extracted was initially analyzed by ChatGPT in a laboratory setting and further examined through

---

[1] *Garbage in, garbage out* (GIGO) is a concept in computer science, according to which incorrect, distorted or low-quality („garbage") data leads to incorrect results, even if the algorithm used in its processing is correct..

comparison with a test of the ability of AI to analyze information and predict future events.

It is important to note that the models discussed in this paper were developed in collaboration with AI services. This involved not only ChatGPT but also other platforms and services like Bing, BARD, and various plugins. Therefore, it is accurate to say that the article was co-authored with the assistance of AI, which has become a common practice in the production of scientific articles. This situation presents an ethical dilemma regarding authorship and introduces a new risk: the possibility of incorrect information. To mitigate this, the author has reviewed and edited all content generated by AI. References are provided for any text that is AI-generated.

Literature Review

Most scientific articles published on prompt engineering so far are optimistic about AI, and the majority originate from what we refer to as the "data sciences". While most articles are technical in nature, some also address how AI is utilized, for example, in education. It is possible that other critical articles that do not use "prompt engineering" as a keyword are therefore overlooked in this study.

Wang et al. (2023a) express optimism about prompt engineering in computer vision, anticipating improvements in models and novel applications. They advocate for further research and exploration into techniques like *prompt fine-tuning* and *knowledge distillation* to optimize *visual recognition systems*. According to (Heston, Khun, 2023), prompt engineering is essential for the effective use of generative language models (GLMs), a type of artificial intelligence (AI) that utilizes machine-learning techniques to produce human-like text. There is emphasis on the necessity of *well-crafted prompts* to achieve desired results, highlighting their significance in personalized learning and interactive engagement. The importance of prompt engineering is important for effectively using Large Language Models (LLMs) like ChatGPT, noting its crucial role in writing and editing (Meyer et al., 2023). They point out that prompt engineering requires expertise and is not trivial. The articles are part of early calls for everyone to go to YouTube and learn how to become a prompt engineer.

In their survey paper, Liu et al. (2023) underscore the importance of prompt engineering, emphasizing the need for appropriate inputs and effective answer spaces. More importantly, they introduce two new key components: "*Prompt Template Engineering*" and "*Prompt Answer Engineering*". "Prompt Template Engineering" focuses on crafting and refining input prompts, involving the development of initial templates, refinement for clarity and effectiveness, the introduction of variables for dynamic user-specific data insertion and continuous testing and iteration to enhance performance. "Prompt Answer Engineering" deals with processing and refining AI-generated responses to meet user needs, including removing irrelevant content, formatting responses for readability, applying post-processing steps like translation or summarization, and ensuring quality and reliability.

Yeadon and Hardy (2023) raise several critical concerns about the role of prompt engineering in AI in physics education, including vulnerability to automated completion, difficulty in discerning AI-written text, rapid advancements in AI, and other ethical considerations. These concerns highlight the need for educators to stay aware of AI's evolving capabilities and adapt their teaching methods accordingly. Said differently, there came a point this winter when many teachers around the world realized that they had to move away from written to oral examinations. In the cases when teachers did not adapt, the students quickly gained an advantage and were able to improve their grades.

Beganovic et al. (2023) also emphasizes the importance of good prompt engineering in using ChatGPT effectively during its rapid development phase. Alkaissi and McFarlane (2023) tested the same problems using BARD, while Henderson et al. (2023) studied the consequences of AI speech services. They also acknowledge the challenges of good advice development and the process of creating a *pattern catalogue*. The authors highlight the need for excellent *cue design* examples to attract cue designers and simplify *the rapid construction process*. They also point to the time and effort required to develop effective prompts and discuss the potential benefits of incorporating rapid model catalogues into the construction process to enhance ChatGPT's performance. "Prompt Tuning with Rules (PTR)" is a technique that may involve the fine-tuning of prompts using specific rules or constraints to improve the performance and relevance of AI models' responses. A "pattern catalogue in AI" refers to the collection of predefined patterns, templates, or best practices used to solve common problems in AI development. It provides a structured approach to designing and implementing solutions, offering guidance on various aspects ranging from design patterns and data preprocessing to algorithm selection, deployment strategies, ethical considerations, and security practices. "Cue design" in AI involves creating cues or signals that AI systems use to communicate with users. Effective cue design enhances user experience and trust, providing visual, auditory, haptic, interactive, and textual cues to create intuitive and engaging AI applications.

Lou et al. (2023) raise two specific concerns about prompt engineering: its lack of *user-friendliness* and *application constraints*. These concerns highlight the need for more user-friendly prompt engineering tech-

niques and an exploration of alternative instruction types for various natural language processing (NLP) tasks. Liu et al. (2023) outline critical considerations for prompt engineers, including the selection of *prompt templates* and *verbalizers*, the impact on recommendation performance, challenges like data constraints, and issues related to knowledge transmission and injection. Wang et al. (2023b) delve into the effectiveness of various prompt designs on Boolean query generation, offering insights into each design's strengths and limitations. Fiannaca et al. (2023) express concerns regarding prompt programming challenges, highlighting the need for tools that support prompt creation and editing effectively. Watson et al. (2023) highlight potential safety and security issues in prompt engineering, noting that crafting effective prompts is as crucial as the engineering aspect itself.

On non-technical contributions, Bondielli et al. (2023) discuss challenges in *multimodal fake news* detection, emphasizing the need for models that understand the interplay between text and image in disinformation generation. Seidenglanz and Baier (2023) describe mixed feelings toward AI in the PR world, advocating for a shift in focus in PR education toward more reflective practice and critical thinking. Budhwar et al. (2023) highlight the potential risks and challenges associated with AI innovations, including job displacement and the need for skill development. Mahmood et al. (2023) address *content repetitiveness* in voice interactions, suggesting further exploration of prompt engineering to improve voice assistant behavior. Chang et al. (2023) raise ethical concerns due to reliance on prompt engineering, as it shifts responsibility from the model to the engineer, potentially leading to biased or misleading outputs and GIGO problems.

Srivastava et al. (2023) also mention concerns related to bias, safety, and correctness in chatbots due to prompt engineering. Bahrami et al. (2023) highlight the limitations of manual design in prompting methods, emphasizing the need for more automation. Zhang et al. (2023) outline challenges in using AI tools in design, including *parameter adjustment*, understanding *domain-specific terms*, generating realistic images, balancing designer intent and AI accuracy, interpreting architectural styles, providing output variation, and integrating AI into design practice. Thoring et al. (2023) express concerns about the complexity of prompt engineering in AI-supported design, foreseeing it as a future skill for designers but noting the challenge of creating prompts that accurately capture design context and requirements. These first reactions to AI in the months following its launch are mostly within what could be expected and resonate well with what experts have expressed during TV and media interviews.

Based on the review, we selected 20 of the most relevant articles for an analysis of content (Table 1). The findings from the analysis of the 20 scientific articles will be further explained as shown in Table 2.

The findings highlight the multifaceted challenges and opportunities in prompt engineering, emphasizing the need for careful consideration of ethical issues, including how to avoid fake news, automation, user experience, and the balance between art and engineering in developing effective prompts. The future of prompt engineering appears promising but requires continuous effort in addressing its limitations and ethical concerns while exploring its potential in various applications, including computer vision and beyond.

So far, this paper has provided a comprehensive overview of various concerns and considerations raised by scholars regarding AI and prompt engineering. However, there are also critical comments and areas that are *not* explicitly addressed in the literature, what we understand as research gaps (Table 3).

These are concerns not yet raised in the existing literature for the keyword "prompt engineering". A study with numerous keywords may detect more articles and fewer gaps.

Addressing these areas is crucial for a more holistic understanding and the responsible practice of AI and prompt engineering. We will come back to how they can be addressed.

However, how does one evaluate AI's performance as an active information worker? To find out, we performed a laboratory test of Societal Analysis using different AI applications and plug-ins.

Testing Capabilities of Analysis and Predictions: Business Intelligence

The author uses the term *Business Intelligence* to describe the practice of using software for *Competitive and Market Intelligence*. During the last several years, industry has tended to prefer the terms "insights" and "intent data" to "intelligence", but the meaning is much the same: important information for making decisions.

What are the major differences as we go from BI to AI? Kumar (2017) pioneered the description of how information analysis has been transformed due to the advent of Artificial Intelligence (AI). In data-driven decision-making, it is imperative to understand the fundamental differences between Business Intelligence (BI) and AI: *While BI is proficient at transforming extensive and diverse data into a coherent narrative and presenting clear data visualization, it typically does not provide actionable insights or suggest specific managerial decisions.* The primary focus of BI is to enhance the efficiency of data collection, reporting, and analysis processes. This allows businesses to improve the quality and consistency of their data collection efforts.

Table 1. **Summary of the Selected Articles for Literature Review, by Field**

Authors	Object of Analysis	Concerns
Data science		
Bahrami et al., 2023	Automation & Optimization	The template and mapping function in the prompting method need to be designed manually, which can be a limitation The authors suggest that automating the process of choosing suitable verbalizations and developing automatic template generation algorithms could address these concerns.
Srivastava et al., 2023	Development & Ethical Considerations	The authors caution that reliance on prompt engineering raises ethical issues and risks. They mention that prompt engineering can potentially lead to biased or misleading outputs, as the responsibility of generating accurate and unbiased responses is shifted from the model to the prompt engineer.
Chang et al., 2023	Development & Ethical Considerations	The authors have concerns about the repetitiveness of content in voice interactions. They observed that ChatGPT's responses can be repetitive, which was also pointed out by participants in their interviews. This repetitiveness can make the interactions tire-some for users.
Mahmood et al., 2023	User Experience & Interaction	This article addresses the difficulty of multimodal fake news detection, the need for models combining multiple modalities, and the importance of understanding the inter-play between text and images in generating disinformation. While the sources do not provide a comprehensive list of risks, it can be inferred that the risks of fake news in-clude spreading misinformation, manipulating public opinion, eroding trust in the me-dia, and potentially influencing social, political, and economic outcomes.
Bondielli et al., 2023	Multimodal Challenges	The authors mention that prompt programmers often need to perform editing opera-tions over semantically meaningful regions of their prompt, such as inserting examples, renaming keywords, and refactoring templates.
Fiannaca, 2023	Programming & Editing Challenges	This study explores the effectiveness of different prompt designs and their impact on the quali-ty of the generated Boolean queries. By comparing the performance of dif-ferent prompt types, the researchers gain insights into the strengths and limitations of each approach.
Wang et al., 2023b	Effectiveness & Impact	Choosing the appropriate prompt template and verbalizer: the authors emphasize that the choice of prompt template and verbalizer can greatly impact recommendation performance.
Liu et al., 2023	Automation & Optimization	The authors emphasize the importance of prompt engineering in the rapid develop-ment phase of using ChatGPT. However, they also acknowledge the challenges of good advice devel-opment and the process of creating a pattern catalogue.
Beganovic et al., 2023	Challenges in Prompt Engineering	The authors posit that the success of LLMs in generating desired outputs is highly de-pendent on the choice of text prompts. Prompt engineering involves carefully crafting and iterating on the prompts to achieve the desired results. The authors mention that prompt engineering is not always trivial and can require expertise.
Meyer et al., 2023	Success Dependency & Expertise Requirement	The authors emphasize the need for designing appropriate inputs for prompting meth-ods and to search for an effective answer space and mapping to the original output. Prompt template engineering and prompt answer engineering are two key aspects of prompt engineering.
Liu et al., 2023	Challenges in Prompt Engineering	They emphasize the need to design appropriate inputs for prompting methods and to search for an effective answer space and mapping to the original output. Prompt template engineering and prompt answer engineering are two key aspects of prompt engineering.

Currently, BI providers are diligently working to incorporate AI capabilities into their software. Over the past three years, there has been a 50% increase in the adoption of BI solutions, according to the industry itself. Companies such as SAP, Microsoft, Oracle, and Tableau have developed BI tools that are designed to revolutionize various traditional business functions, including but not limited to Human Resources, Sales, and Marketing.

A significant trend in the BI sector is the movement toward *self-service analytics*. This approach allows users to access and analyze data without excessive reliance on support, with a focus on user-friendly BI tools and a simplified data model. In the past, individuals lacking technical expertise had to depend on centralized data teams for their data inquiries, leading to delays between data requests and the acquisition of insights. Today, business professionals are given access to the data insights they need promptly, in real-time when possible, facilitating informed and timely decision-making. AI is a driving force behind this transformative change. A consequence is that *Cloud Solutions* are bowing to the advantage of *Edge Computing*, whereby applications are run as close as possible to where the data is generated.

AI's Proficiency in Foresight (Holistic Approach) and Forecasting (Data-Driven): The Crystal Bowl Conundrum

In this section of the paper, we explore AI's capabilities in making foresight (qualitative and quantitative) and forecasting (predominantly quantitative) predictions, illustrated with simple examples in the form of prompts in a laboratory setting (Table 4).

These predictions are speculative and based on current trends and developments, according to the ChatGPT

Authors	Object of Analysis	Concerns
		Table 1 continued
		Design
Thoring et al., 2023	Challenges in Prompt Engineering	The challenge of creating appropriate prompts that capture the design context and requirements
Zhang et al., 2023	Automation & Optimization	AI's limited understanding of domain-specific design terms and concepts. AI generating images that are unrealistic or not suitable for architectural purposes.
Lou et al., 2023	Application Constraints, Effectiveness & Impact	Not user-friendly: prompt engineering is typically designed for pre-trained language models (PLMs) and often involves using incoherent words or internal embeddings pre-ferred by the model. However, these prompt designs are difficult for humans to under-stand and may run counter to human intuition.
Watson et al., 2023	Art & Engineering Balance	There is as much art as engineering in developing effective prompts. They also men-tion that experimentation with prompts may lead to phenomena never seen before, even in familiar models, which can create potential safety and security risks.
		Education
Yeadon, Hardy, 2023	Ethical & Responsible AI	Vulnerability to automated completion: unsupervised coding and short-form essays, which are commonly used assessment methods are vulnerable to automated completion by language models.
		Human Resources
Budhwar et al., 2023	Future of Work & Skill Development	Employers are likely to use these innovations to displace jobs such as software engineers, data scientists, and business intelligence analysts. This raises questions about the future of work and the need for individuals to develop new skills for interacting with and eliciting knowledge from these AI tools.
		Medical Sciences
Heston, Khun, 2023	Challenges in Prompt Engineering	Well-crafted prompts yield good responses from the GLM, while poorly constructed prompts can lead to unsatisfactory responses. The authors highlight the importance of prompt engineering in effectively communicating with GLMs to maximize their potential in personalized learning, unlimited practice opportunities, and interactive engagement. However, they also acknowledge the challenges associated with prompt engineering, such as ensuring accuracy, mitigating bias, maintaining privacy, and avoiding excessive reliance on technology.
		PR / Communications
Seidenglanz et al., 2023	Ethical & Responsible AI	While the concerns are clear - ethics, responsibility, accountability, transparency, compe-tence, and social impact – the solutions to them require systemic changes and long-term approaches. Responding to AI as a wicked problem, complex and with many known and unknown unknowns, requires a reorientation of the PR/Comms profession's focus.
		Review Paper
Wang et al., 2023a	Future Directions & Optimism	The authors of the review paper are optimistic about the future of prompt engineering in com-puter vision. They believe that prompt engineering has the potential to revolutionize the field by improving current models and enabling the creation of novel applications

Note: This and subsequent tables are based on the content generated by the OpenAI service ChatGPT. Data retrieved within the period July 10 – September 9, 2023, from https://www.chatgpt.com.

disclaimer, but they are also of the same quality or better than what many humans (intelligence analysts, futurists or researchers) can produce, based on the same data.

The predictions given by ChatGPT can also change depending on the date asked and what words were used in the prompt without changes to the quality of the analysis. The AI is also good at explaining each part in depth when follow-up questions are asked. The comprehensive analysis delivered to the follow-up questions is even of higher quality and could not have been done by most entry-level analysts with a university education. We tried this for all ten predictions and even extended the list to twenty predictions with the same quality in the responses.

We want to know the sources of these answers, but this is not possible with the current 4.0 version of ChatGPT. There are, however, AI systems that provide sources.

Comparing ChatGPT to Bing and Chatsonic

While Bing can display its sources, these typically include horoscopes and webpages of similar quality, resulting in predictions that are not only unreliable but fundamentally different and false.

We also tested a third AI chat, Chatsonic, for comparison. Although the predictions from Chatsonic are less convincing and substantial than those collected from ChatGPT, one advantage of Chatsonic is that it provides more quality links, like Pew Research.

When we inquired further about the three sources used, the AI provided a vague response, attributing the insights to "general knowledge". Even after pressing the AI for more details, considering it cited three specific sources, the system merely clarified that a significant amount of information from these sources is consistent with general knowledge.

Analysis	Explanation of Main Concerns
Table 2. **Analysis of Articles for the Literature Review**	
Challenges in Prompt Engineering	Design Complexity: Crafting appropriate prompts that encapsulate design context and requirements is challenging. Limited Understanding: AI struggles with domain-specific design terms and concepts, leading to unrealistic or unsuitable outputs for certain applications, such as architecture. Manual Processes: Template and mapping functions in prompting methods are manually designed, limiting the efficiency and scalability of prompt engineering.
Automation & Optimization	Automation Need: There is a call for automating the process of choosing suitable verbalizations and developing automatic template generation algorithms to address manual limitations.
Ethical & Responsible AI	Ethical Concerns: Prompt engineering raises issues related to bias, safety, correctness, ethics, responsibility, accountability, transparency, and social impact. Trust & Reliability: The responsibility shift from the model to the prompt engineer can affect the trustworthiness and reliability of Large Language Models (LLMs).
Future of Work & Skill Development	Job Displacement: Innovations in prompt engineering may displace jobs, necessitating the acquisition of new skills for interacting with AI tools. Data Ownership & Accountability: Concerns about data ownership, content moderation, and decision accountability need addressing.
User Experience & Interaction	Repetitiveness: AI responses can be repetitive, affecting user experience. User-Friendliness: Prompt engineering designs are often not intuitive for non-experts, limiting accessibility and usability.
Application Constraints	Limitations in NLP Tasks: Short and simplistic prompts may not capture the complexity of real-world NLP tasks.
Multimodal Challenges	Fake News Detection: Understanding the interplay between text and images is crucial for multimodal fake news detection.
Art & Engineering Balance	Creative Process: Developing effective prompts involves both artistic and engineering skills, with experimentation leading to unforeseen phenomena and potential risks.
Programming & Editing Challenges	Lack of Predefined Grammar: Prompt programmers face challenges in editing prompts due to the absence of a well-defined programming language for prompts.
Effectiveness & Impact	Prompt Design Impact: Different prompt designs affect the quality of generated outputs, with the choice of template and verbalizer significantly impacting performance in various tasks.
Rapid Development & Ethical Considerations	Vulnerabilities & Ethical Issues: Rapid advancements bring challenges like vulnerability to automated completion, difficulty in discerning AI-written text, and ethical considerations in education and other fields.
Success Dependency & Expertise Requirement	Expertise Needed: Successful prompt engineering requires careful crafting and iteration, with a need for expertise in designing appropriate inputs and searching for effective answer spaces.
Future Directions & Optimism	Potential in Computer Vision: Prompt engineering is seen as a revolutionary tool in computer vision, with optimism about its future applications and improvements to the current models.

Another issue with all AI services tested is their tendency to retract statements only to reintroduce them later in the conversation. While this is likely to improve in future versions, the necessity of such roundabout communication remains questionable. This problem is referred to as the Crystal Bowl Conundrum in this study. It describes a situation where answers are given without adequately citing sources, where the explanations regarding the origin of the information are unclear, and where the output of answers changes if the prompter objects. This is akin to the response one might expect from a fortune teller who seeks returning customers, posing a risk for any commercially developed AI. A closely monitored AI developed within a closed-end political system, like a dictatorship, would represent another form of the Crystal Bowl Conundrum risk.

Kumar et al. (2017) identified a similar issue, referring to it as the Black Box problem: while persistent follow-up inquiries can yield insights, the exact workings of the "bowl" in each case remain elusive. In future versions of AI it would therefore be expected that the user is shown where the information comes from and how it was generated.

The beauty of AI is that we can confront it with its own shortcomings. ChatGPT acknowledges the metaphorical similarity to a crystal ball but also highlights differences: "A crystal ball lacks access to data sources and processing capabilities, and it doesn't make predictions in the same manner", ChatGPT argues, which is correct. The AI also learns from this conversation and improves in future versions.

AI at Forecasting can also offer probabilistic projections. For instance, we asked which country would be

Analysis	Research Gaps
	Table 3. Concerns Not Raised in the Literature
Ethical Considerations	While there is a brief mention of ethical concerns, there isn't a deep dive into the ethical considerations and dilemmas that engineers might face while working with AI and craft-ing prompts. Issues like privacy, consent, and the potential harm AI might cause to indi-viduals or communities are not elaborated upon.
Bias and Fairness	Although bias is mentioned, the current research does not extensively discuss the inher-ent biases that might be present in AI models and how prompt engineering might inad-vertently amplify these biases. There is no discussion on how to mitigate or address these biases effectively.
Transparency and Explainability	The literature does not address the transparency and explainability of AI models and prompts. It is crucial for users to understand how decisions are made by AI and prompt engineers play a role in making AI decision-making processes more transparent and un-derstandable.
Accountability and Responsibility	While there is mention of shifting responsibility, the literature does not delve into who is ultimately accountable and responsible when AI models, guided by engineered prompts, make mistakes or cause harm.
Regulatory Compliance	There is no discussion on the legal and regulatory landscape surrounding AI and prompt engineering. Compliance with existing and emerging laws and regulations is crucial for ethical and legal AI deployment.
Professional Development and Training	The need for continuous learning and development for prompt engineers is not ad-dressed. As AI and related technologies rapidly evolve, professionals need to stay up-dated on the latest tools, techniques, and best practices in the field.
User Experience	While user fatigue is mentioned in the context of repetitiveness, there is not a broader discussion on user experience, including how to make interactions with AI more user-friendly, accessible, and inclusive for diverse user groups.
Security Measures	Although safety and security are mentioned, there is not a detailed discussion on the specific security measures and protocols that need to be in place to protect AI systems from malicious attacks and unauthorized access.
Sustainability	The thread does not mention the environmental impact of running large-scale AI models and the importance of sustainable practices in AI and prompt engineering.
Public Perception and Trust	While trust is briefly mentioned, there has not been an in-depth discussion on building and maintaining public trust in AI systems and the role of prompt engineering in foster-ing that trust.
Economic Impact	While job displacement is discussed, the broader economic impact, including the crea-tion of new jobs and industries due to AI and prompt engineering, is not explored.

the world's economic superpower in 2026 and 2035 to observe if there were any variations in the predictions for these intervals: "Who will be the greatest future economic superpowers?" The answer given for 2026 and 2035 is equivalent to that of a good analyst. Probabilistic Projections for 2035 are also qualified and show a realistic difference from the previous 2026 period. When we press it on the rivalry between the US and EU, the answers are also qualified (see Table 5). ChatGPT also explains how it makes the calculations (Table 6). ChatGPT allocated 5% or 10% to adjust up or down from the baselines, depending on the significance of each factor or variable. This methodology is of the same quality as found in the industry, for example, as explained in the bestselling book "Superforecasting" (Tetlock, Gardner, 2016). AI can also reflect on its own capacity and abilities in the future (Table 7).

This means that AI can provide analyses of societal events as well as or better than many intelligence analysts or market researchers. It even possesses the ability to reflect on its shortcomings, a trait less commonly found in humans. Additionally, AI can demonstrate its thought processes and continuously improve.

Another great advantage of AI is that it can show different decisions for different stakeholders given a specific problem. It can compare our decisions with those of our competitors, politicians, activists, and so on. (Table 8). This facilitates, for example, the execution of "war games", where the computer anticipates what opponents will do in response to each of our decisions.

Analysis and Implications

Intelligence analysts can be divided into entry-level, intermediate, senior, and advanced analysts. The laboratory test in this study shows that AI can now operate at the level of a senior analyst, or better. In some cases, it can replace strategic thinking and leadership. It is worth noting that AI itself thinks it is performing less well than a senior analyst, showing some signs of modesty. It can also understand geopolitical contexts, it has the ability to anticipate human behavior and engage in ethical decision-making, which makes it, in many cases, as good as an advanced analyst.

In this Brave New World, the role of decision-makers will change dramatically. CEOs and other top managers will no longer be inexplicable magicians

	Table 4. **Application of AI for Societal Analysis**
Question: «Can you give some speculative predictions about what can happen in 2024?»
Area	**Prediction**
AI and Automation Proliferation	AI might permeate even more aspects of daily life, from automated transport systems and smart homes to personalized health and wellness advice.
	The job market may experience a shift, with an increased demand for specialists who can manage and optimize AI systems, while some traditional jobs might face obsolescence due to automation.
Sustainable Technologies	AI might permeate even more aspects of daily life, from automated transport systems and smart homes to personalized health and wellness advice.
	The job market may experience a shift, with increased demand for specialists who can manage and optimize AI systems, while some traditional jobs might face obsolescence due to automation.
Space Exploration	Space tourism might become more accessible to the public, with several private companies potentially offering suborbital flights.
	There may be significant advancements in exploring Mars, and perhaps, the establishment of the initial phases of a human colony on the red planet.
Healthcare Innovations	Telemedicine and remote healthcare services might become the norm, providing healthcare access to remote and underserved areas.
	Advancements in personalized medicine, utilizing genetic information to tailor treatments, might provide breakthroughs in managing chronic and genetic conditions.
Global Politics and Economy	The global economy might witness new leaders emerging, with countries that have managed to harness technology and sustainable practices effectively taking the lead.
	The geopolitical landscape might shift with the emergence of new alliances and partnerships, particularly in response to global challenges like climate change and cybersecurity threats.
Education and Remote Work	Hybrid models of work and learning might become more established and refined, providing people with flexible options to manage their work-life balance.
	Educational institutions might incorporate more technology-driven learning experiences, such as VR and AR, to enhance remote learning.
Cybersecurity	With the increasing reliance on digital platforms, cybersecurity might become a critical concern for individuals, corporations, and nations alike.
	New forms of cybersecurity threats might emerge, necessitating the development of advanced defense mechanisms.
Social Media and Virtual Reality	Social media might evolve to incorporate more elements of virtual and augmented reality, providing more immersive and interactive online experiences.
	Virtual reality might become a common platform for social interaction, work, and entertainment.
Biotechnology	Advancements in biotechnology might enable breakthroughs in combating diseases, aging, and even enhancing human capabilities.
	Ethical debates regarding bioengineering and genetic modifications might become more prevalent.
Cultural and Social Shifts	Societies might witness shifts in cultural and social norms, particularly in response to technological advancements and global challenges.
	Issues like privacy, data security, and ethical use of technology might become central to societal debates and policymaking.

whose decision-making processes can stay murky – thus much of their claim to being "business geniuses" – but will have to select decisions from a predetermined menu of traceable intelligence, decisions which will again be measured. The system will also calculate probabilities for the outcomes of alternative decisions. This will again affect top managers' salaries, which will become more aligned with those of other employees with more responsibility, or so could be expected.

The aim of intelligence or insights has always been to facilitate better decision-making. With AI systems, we will witness the full integration of these functions. Management with AI support means that employees choose a decision from a menu of options and can see the sources of the information and understand how it is analyzed. We are already there.

For the moment, though, in version GPT-4 we are more concerned with AI "hallucinations" and other types of errors given to us as output for our queries. All this information will need to be checked through both human discernment and algorithmic cross-checks. At present, this development necessitates new professional functions at the organization: the *Information Quality Control (IQC) Manager* or employee. The term is used as a parallel to the well-known *Quality Manager*, who ensures that all products of the company meet consistent standards. The IQC function is entrusted with the crucial responsibility of meticulously vetting data for inaccuracies before the intelligence is passed on in the system to decision-makers. It is vital to separate this function from the one person making the AI queries, the prompter. Liu et al. (2023) make a similar, but distinct, sepa-

Table 5. AI Probability Assessments on the Prospects for the Greatest Future Economic Superpowers

Country / Region	AI Estimation Statements
AI answers on question 'Who will be the greatest economic superpowers in 2026?'	
China	There is a high probability (70%-80%) that China will continue its trajectory to become the world's largest economy by 2026, given its growth rates and strategic initiatives.
US	There is a moderate probability (50%-60%) that the US will maintain its position as the world's top or second-largest economy, depending on various internal and external factors.
Europe/ EU	There is a high probability (70%-80%) that the EU will remain a major global economic bloc, but it is unlikely to surpass the US or China in terms of total GDP.
AI answers on question 'Who will be the greatest economic superpowers in 2035?'	
China	There is a high probability (70%-80%) that China will be the world's largest economy by 2035. However, its growth rate might be closer to that of developed economies.
US	There is a high probability (65%-75%) that the US will be the second-largest economy. Its influence in tech, finance, and global diplomacy will remain significant
Europe/ EU	There is a moderate to high probability (60%-70%) that the EU will maintain its position as a major global economic bloc. Its role in global diplomacy, trade, and technology will be crucial
AI assessments of the comparative positions of US and Europe/EU as future economic superpowers	
US	There is a high probability (70%-80%) that the US will hold second place in terms of GDP by 2035. The US's strengths lie in its technological innovation, financial markets, energy resources, and entrepreneurial ecosystem. Additionally, the US dollar's role as the world's primary reserve currency provides economic leverage.
Europe/ EU	There is a moderate probability (20%-30%) that the EU could surpass the US to take second place. While the EU has a large and diversified economy, several challenges might hinder its growth relative to the US. These challenges include demographic decline, regulatory complexities, and potential geopolitical tensions within and outside the union.

ration between "Prompt Template Engineering" and "Prompt Answer Engineering," where the first formulates input prompts and the second processes the answers to meet the needs of quality and reliability for the decision-maker. In its work, IQC must be able to use sources other than AI systems, such as books and observations, including non-digital sources.

A working process for an intelligence analyst could look like the figure below.

A number of other knowledge workers, such as researchers and librarians, may not necessarily work with a separate IQC simply due to budget reasons but will need to perform these controls themselves and are already doing so. In professions where the

implication of accurate information or intelligence is essential, such as financial analysts, data scientists, and intelligence analysts, it will often be required.

If the analyst or researcher wants to stay relevant, he must engage with YouTube University courses, delve into the intricacies of prompt engineering, master Python programming, and experiment with the latest plugins designed for ChatGPT, all of which are improving daily.

The focus is no longer solely on the accuracy of the information obtained, but also on the speed of its delivery, the seamless integration of various software applications, and the dynamics of collaborative group work. Currently, any piece of information can be easi-

Table 6. Explanations by ChatGPT on How it Makes the Calculations

Item	Explanations
Starting Point	Begin with a baseline assumption that, given historical data and the status quo, the US and the EU have an equal chance (50-50) of being in second place by 2035.
Adjusting for Economic Momentum	The US has shown consistent economic growth and resilience in the face of global challenges. Given its historical trajectory and the dynamism of its economy, we might adjust the probability in favor of the US by an additional 10%. This brings the US to 60% and the EU to 40%.
Technological Leadership	The US has historically been at the forefront of technological innovation, especially in sectors that are expected to drive future economic growth (e.g., AI, biotech). Given this advantage, we might further adjust the probability in favor of the US by another 5%. This brings the US to 65% and the EU to 35%.
Geopolitical and Regulatory Factors	The EU faces challenges related to regulatory complexities, potential geopolitical tensions, and internal unity. These challenges might hinder its economic growth relative to the US. Adjusting for these factors, we might further tilt the probability in favor of the US by another 5%. This brings the US to 70% and the EU to 30%.
Final Probabilities	Based on the above adjustments, the final qualitative estimates are 70% for the US and 30% for the EU.

Areas of AI Capabilities	Perspective	
	Five years ahead	Ten years ahead
Enhanced Data Processing and Analysis	AI will be able to sift through vast amounts of data at unprecedented speeds, making the process of data collection and preliminary analysis more efficient. This will allow intelligence professionals to focus on more complex tasks that require human intuition and judgment.	Advanced AI models might be able to not only process data but also predict future trends based on historical data and current events. This predictive capability could be invaluable for both market research and state intelligence services.
Automated Open Source Intelligence (OSINT)	AI will become a primary tool for OSINT. It will be able to monitor public sources in real-time, translate languages instantly, and detect anomalies or important information based on predefined criteria. This will significantly enhance the capabilities of state intelligence services and business intelligence professionals.	AI-driven OSINT tools might be able to identify disinformation campaigns, trace their origins, and provide counter-strategies. They could also integrate data from various sources to create a comprehensive picture of a situation or market trend.
Decision Support Systems	AI will assist decision-makers by providing them with data-driven insights and recommendations. For market researchers, this means better consumer insights, product recommendations, and market entry strategies.	AI systems might be integrated into the decision-making processes of organizations and state agencies, offering real-time insights and even simulating the outcomes of potential decisions.
Human-AI Collaboration	The intelligence profession will see a rise in hybrid teams of humans and AI working together. While AI handles data processing and pattern recognition, humans will handle tasks requiring emotional intelligence, cultural understanding, and ethical considerations.	Training and collaboration methods will evolve, with professionals learning to work alongside AI more seamlessly. There might be specialized roles focused solely on interpreting and guiding AI analyses.
Ethical and Security Concerns	As AI becomes more integrated into the intelligence profession, concerns about data privacy, misuse of AI, and potential biases in AI algorithms will become more prominent. There will be a push for regulations and standards.	Advanced security measures will be developed to protect AI systems from adversarial attacks. Ethical guidelines and international agreements might be established to govern the use of AI in intelligence.
Job Transformation and Reskilling	While AI will automate certain tasks, it will also create new roles. Professionals will need to reskill, focusing on areas where human judgment is irreplaceable.	The intelligence profession might see a shift in job roles, with more emphasis on AI management, interpretation, and strategy than on data collection.

Table 7. **Reflections of AI on its Own Capacity and Abilities in the Future**

ly converted into structured tables, detailed diagrams, and vibrant imagery as we see a rapid Integration of Intelligence Analysis and Decision-Making.

Future Studies

ChatGPT can also suggest future research, even with hypotheses to be tested (Table 9). These research projects and hypotheses are designed to explore in greater depth the implications of rapid advancements in AI, examining their effects on society, the workforce, and individual rights.

Upon reviewing the suggestions, however, most of them seem rather intuitive or more common-sensical. Some of the faults can be attributed to the inadequacy of the prompts provided. To address this, we refined the prompts for this study, and the improved results are more relevant (Table 10).

We can also inquire about the types of apps or tools the AI would require to execute these projects, as well as identify potential limitations that necessitate human intervention for conducting the research. To conduct the research projects, a combination of tools, apps, and methodologies would be necessary. Below is a breakdown provided by ChatGPT (Table 11).

AI is already nearly capable of independently completing entire research projects, raising questions about the way and the extent to which we perform research altogether. The author has in many ways, already been reduced to a mere prompter, and this development will only become clearer. This calls into question the authenticity of being an "author." It is already a collaborative effort. Moreover, the "readers" or "receivers" will also increasingly be AI systems as we move into a world where information is both produced and consumed by AI, where humans take the role of *information administrators* and facilitators.

In the production of intelligence, it is crucial to distinguish between human and machine input. More generally, future research should focus on questions about ethics and responsibility in decision-making involving AI.

Conclusions

The role of the prompter in this paper has been bifurcated into two distinct functions: the prompt engineer, who supplies standard prompts, and the Information Quality Control (IQC) manager, responsible for fact-checking. The separation of these functions is

Decision options	Description
Table 8. Decision Options for Different Stakeholders for a Specific Problem Proposed by ChatGPT	
Politician	
Legislation on AI Ethics and Privacy	Advocate for and support the creation of stringent regulations that address the ethical use of AI, especially in surveillance, to protect citizens' privacy rights.
Promote Digital Literacy	Launch initiatives to educate the public about the implications of the 'Total Intelligence Society' and the importance of digital literacy in the age of AI.
Support AI Research and Development	Allocate funds and resources to foster AI research, ensuring that the nation remains at the forefront of technological advancements.
Collaborate with Intelligence Analysts	Engage with intelligence analysts to harness AI's potential in policy-making, leveraging real-time data and insights.
Public Communication	Use AI-enhanced tools to analyze public sentiment and tailor communication strategies, ensuring transparency and building trust
Manager of a Large Law Firm	
AI-enhanced Legal Research	Invest in AI tools that can swiftly sift through vast legal databases, extracting relevant case laws and statutes.
Continuous Learning	Encourage attorneys to undertake courses on AI, prompt engineering, and related technologies to stay updated and competitive.
Client Data Protection	Implement robust AI-driven cybersecurity measures to protect client data, given the increasing risks in the digital age.
Automate Routine Tasks	Use AI to automate routine tasks such as contract analysis, ensuring that attorneys can focus on more complex legal challenges.
Collaboration Platforms	Adopt AI-enhanced collaboration platforms that allow for seamless integration of diverse software applications, fostering efficient teamwork.
University School Teacher	
AI in Curriculum	Integrate AI topics into the curriculum, ensuring students are prepared for the evolving job market.
Personalized Learning	Utilize AI tools to offer personalized learning experiences, tailoring content to individual student needs.
Engage with Digital Tools	Familiarize oneself with AI plug-ins and tools like ChatGPT to enhance teaching methodologies and stay updated.
Promote Authentic Content Creation	While acknowledging the rise of AI in content creation, encourage students to produce «100% made by humans» content, emphasizing the value of human touch in creativity.
Collaborative Learning	Leverage AI-driven platforms that promote collaborative learning, allowing students to work together on projects and assignments in real-time.

imperative for maintaining reliable intelligence. The decision to implement an IQC process hinges on the value of information to an organization and is more likely to be employed by professionals like financial analysts, data scientists, and intelligence analysts. This study introduces a model using AI for processing information or intelligence and shows the rationale for why managers are likely to see lower salaries.

A year into the incorporation of AI, a significant skill disparity has emerged between those proficient in advanced prompt engineering, often self-taught or learned through online platforms like YouTube, and those new to AI services.

A recent *Nature* article (Conroy, 2023) posits that AI's initial use was primarily for grammar checks, coding, and summarizations. However, our study suggests a more profound penetration of AI among researchers, *calling into question the nature of independent research*. We are transitioning to a reality where AI not only generates but also analyzes valuable content, with humans increasingly taking on supervisory roles. Approximately 80% of this article was produced with AI assistance, and it is more likely to be thoroughly "read" by AI than by humans.

The advent of the Internet saw it become a haven for economic fraud. Similarly, AI now facilitates intellectual fraud on a massive scale, with no established watermarking rules, easily removable data origin markers, and the manipulation of AI services to provide misleading assurances of content integrity.

The current literature on prompt engineering has primarily focused on the mechanics of prompt creation, such as crafting appropriate prompts and automating template generation. Ethical discussions are present but lack depth, often touching on safety, correctness, ethics, responsibility, accountability, transparency,

Table 9. **ChatGPT-Proposed Future Research Projects**	
Project topic	**Hypotheses to be tested**
1. The Impact of AI on Content Authenticity	1. The proliferation of AI-generated content will lead to a decline in the perceived authenticity of digital content. 2. The "100% made by humans" label will become a sought-after mark of authenticity in various content domains. 3. The majority of consumers will be unable to distinguish between AI-generated and human-generated content without explicit labeling.
2. The Role of AI in Decision-Making Processes	4. Decision-makers who utilize AI tools will make more informed decisions compared to those who rely solely on traditional methods. 5. The reliance on AI for decision-making will lead to a reduction in the time taken to make complex decisions. 6. There will be an increased demand for Information Quality Control Managers (IQCM) at organizations that heavily rely on AI-driven insights.
3. The Dichotomy in the Workforce due to AI Proficiency	7. Individuals proficient in AI tools and plugins will have a competitive advantage in the job market compared to their counterparts. 8. Organizations with a higher percentage of AI-proficient employees will report increased efficiency and productivity. 9. The gap between AI-proficient individuals and novices will widen, leading to potential socio-economic disparities.
4. The Implications of the 'Total Intelligence Society'	10. The 'Total Intelligence Society' will lead to increased public concerns regarding privacy and individual rights. 11. Governments with stringent AI surveillance regulations will have higher public trust ratings compared to those without. 12. The continuous monitoring in the 'Total Intelligence Society' will lead to behavioral changes in individuals, with a potential increase in self-censorship.
5. The Evolution of Education in the Age of AI	13. Educational institutions that integrate AI topics into their curriculum will produce graduates better prepared for the modern workforce. 14. Personalized learning experiences powered by AI will lead to improved student outcomes and retention rates. 15. The emphasis on collaborative learning through AI-driven platforms will foster a culture of teamwork and interdisciplinary learning among students."

Figure 1. **Summary of the AI Working Process for Valuable Information**

Explanation: The entities are the analysts (1), the AI (2), the control manager (3), the decision-maker (4), and a function that recalls, analyzes, and produces new queries (5).

Source: author.
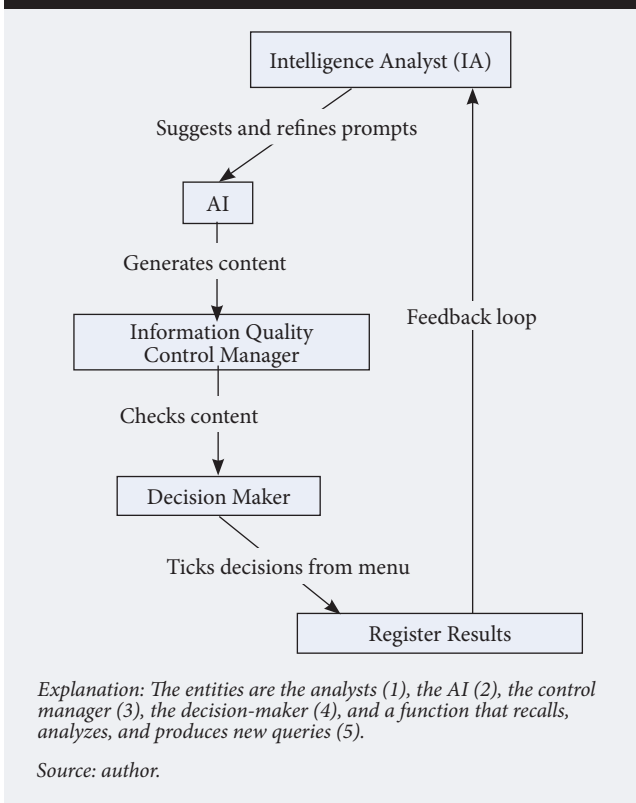
and social impact in a cursory manner. Discussions also extend to the Future of Work and Skill Development, examining the potential displacement of jobs by AI and the need for new skill sets.

The literature review in this paper has identified several research gaps in the field of prompt engineering, notably a lack of in-depth analysis of ethical dilemmas, the impact of inherent biases in AI, the necessity for transparency in AI decision-making, and the environmental footprint of large-scale AI operations. It is essential for prompt engineers to render AI's decision-making processes more transparent and intelligible. While user fatigue and repetitiveness are mentioned, broader issues of user experience and inclusivity are not thoroughly examined. Moreover, the role of prompt engineering in building public trust in AI systems is only superficially discussed.

The scale of investment in AI foreshadows rapid innovation, including the potential merger of AI with robotics, leading to companies operating through prompts and automated production and distribution processes.

AI is currently in an optimistic but tumultuous phase, akin to the early days of automobiles or space exploration, with risks not of physical harm but intellectual manipulation. Yet, we are also in a phase of intense

Table 10. **ChatGPT-Proposed Quantitative Research Projects**

Direct variables	Indirect variables	Hypotheses
Project 1. AI's Influence on Content Authenticity Perception		
AI-generated content consumption frequency	User's perceived content authenticity	1. Increased consumption of AI-generated content correlates with decreased perceived authenticity.
Human-generated content consumption frequency	User's trust in content source	2. Users trust human-generated content more when the source is disclosed.
Project 2. AI's Role in Decision-Making Efficacy		
Number of AI tools used in decision-making	Decision-making speed	3. Greater reliance on AI tools leads to faster but not necessarily more accurate decisions.
Frequency of AI tool usage	Decision-making accuracy	4. Decision-making accuracy is influenced more by the quality of AI tools than the quantity.
Project 3. Workforce Dichotomy and Economic Impact		
Number of AI tools an individual is proficient in	Individual's income	5. Individuals proficient in more advanced AI tools have a higher income bracket.
Years of experience without AI tools	Job market demand for AI proficiency	6. The job market demand for AI proficiency has a positive correlation with economic growth in tech sectors.
Project 4. Privacy Concerns in the 'Total Intelligence Society'		
Number of surveillance AI tools in use by state	Public's perceived privacy	7. An increase in state surveillance AI tools correlates with decreased public perceived privacy.
Frequency of individual's digital interactions	Number of reported privacy breaches	8. Higher frequency of individual digital interactions leads to more reported privacy breaches.
Project 5. AI Integration in Education and Learning Outcomes		
Number of AI tools integrated into curriculum	Student grades	9. Greater integration of AI tools in curriculum leads to improved student grades.
Frequency of AI tool usage in teaching	Student engagement level	10. Frequent usage of AI tools in teaching correlates with higher student engagement but not necessarily better understanding.

Table 11. **Tools and Apps Proposed by ChatGPT for Quantitative Research**

Tools	Apps
Data Collection and Storage	Web Scraper Tools like Scrapy or Beautiful Soup to collect data from the web. SQL databases (e.g., PostgreSQL) or NoSQL databases (e.g., MongoDB) to store and manage large datasets.
Data Analysis	Statistical Software R or Python (with libraries like pandas, numpy, and scipy) for data manipulation and statistical analysis. Machine Learning Frameworks TensorFlow, PyTorch, or scikit-learn for predictive modeling and clustering.
Data Visualization Tools	Tableau, PowerBI, or Python libraries (e.g., matplotlib, seaborn) to visualize data and findings.
Survey Tools	Platforms like Qualtrics, SurveyMonkey, or Google Forms to gather primary data, especially when studying perceptions or behaviors.
Natural Language Processing (NLP)	Tools like spaCy, NLTK, or GPT-based models to analyze textual data, especially when studying content authenticity or sentiment.
Collaboration and Project Management	Platforms like Trello, Asana, or Slack to manage the research process, especially if it involves a team.

learning and are likely to see significant job market shifts in the next few years, including for salaries. The study's laboratory tests suggest that some professions, particularly at the entry and intermediate levels, may face existential threats. Perhaps this can help attract more people to the much-needed professions in craftsmanship instead. Eventually, as production nears full automation, the conversation around Universal Basic Income (UBI) may resurface, particularly in affluent nations. Moreover, the study shows that AI with good prompts is as good as or better than senior intelligence analysts at Societal Analysis and Future Predictions.

As we progress, we will increasingly rely on both our biological and artificial intelligence, perpetually verifying information. In parallel, a societal backlash against the prevalence of AI is probable, with some individuals seeking solace in nature, detached from the technological world. With increased levels of productivity, this may also be economically feasible.

References

Alkaissi H., McFarlane S.I. (2023) Artificial hallucinations in ChatGPT: Implications in scientific writing. *Cureus*, 15(2), 35179. https://doi.org/10.7759%2Fcureus.35179

Bahrami M., Mansoorizadeh M., Khotanlou H. (2023) *Few-shot Learning with Prompting Methods*. Paper presented at the 2023 6th International Conference on Pattern Recognition and Image Analysis (IPRIA),14-16 February 2023, Qom, Iran, https://doi.org/10.1109/IPRIA59240.2023.10147172

Beganovic A., Jaber M.A., Abd Almisreb A. (2023) Methods and Applications of ChatGPT in Software Development: A Literature Review. *Southeast Europe Journal of Soft Computing*, 12(1), 8–12. http://dx.doi.org/10.21533/scjournal.v12i1.251

Bondielli A., Dell'Oglio P., Lenci A., Marcelloni F., Passaro L.C., Sabbatini M. (2023) *Multi-fake-detective at EVALITA 2023: Overview of the multimodal fake news detection and verification task*. Paper presented at the 8th Evaluation Campaign of Natural Language Processing and Speech Tools for Italian (EVALITA 2023), September 7–8, Parma, Italy.

Budhwar P., Chowdhury C., Wood G., Aguinis H., Bamber G.J., Beltran J.R., Boselie P., Cooke F.L., Decker S., DeNisi A., Dey P.K., Guest D., Knoblich A.J., Malik A., Paauwe J., Papagiannidis S., Patel C., Pereira V., Ren S., Rogelberg S., Saunders M.N.K., Tung R.L., Varma A. (2023) Human resource management in the age of generative artificial intelligence: Perspectives and research directions on ChatGPT. *Human Resource Management Journal*, 33(3), 606–659. https://doi.org/10.1111/1748-8583.12524

Chang Y., Wang X., Wang J., Wu Y., Zhu K., Chen H., Yi X., Wang C., Wang Y., Ye W., Zhang Y., Chang Y., Yu P.S., Yang Q., Xie, X. (2023) *A survey on evaluation of large language models* (arXiv preprint 2307.03109). https://doi.org/10.48550/arXiv.2307.03109

Conroy G. (2023) How ChatGPT and other AI tools could disrupt scientific publishing – A world of AI-assisted writing and reviewing might transform the nature of the scientific paper. *Nature, 622*, 234–236. *https://doi.org/10.1038/d41586-023-03144-w*

Davenport T.H., Ronanki R. (2018) Artificial intelligence for the real world. *Harvard Business Review,* 96(1), 108–116.

Fiannaca A.J., Kulkarni C., Cai C.J., Terry M. (2023) *Programming without a Programming Language: Challenges and Opportunities for Designing Developer Tools for Prompt Programming*. Paper presented at the 2023 CHI Conference on Human Factors in Computing Systems, April. https://doi.org/10.1145/3544549.3585737

Henderson P., Hashimoto T., Lemley M. (2023) *Where's the Liability in Harmful AI Speech?* (arXiv preprint 2308.04635). https://doi.org/10.48550/arXiv.2308.04635

Heston T.F., Khun C. (2023) Prompt engineering in medical education. *International Medical Education*, 2(3), 198–205. https://doi.org/10.3390/ime2030019

Kumar M., Mani U.A., Tripathi P., Saalim M., Roy S., Roy Sr. S. (2023) Artificial Hallucinations by Google Bard: Think Before You Leap. *Cureus*, 15(8). https://doi.org/10.7759/cureus.43313

Kumar R. (2017) *Machine learning and cognition in enterprises: Business intelligence transformed*. Heidelberg, Dordrecht, London, New York: Springer.

Kumar D., Taylor G.W., Wong A. (2017) *Opening the black box of financial AI with clear-trade: A class-enhanced attentive response approach for explaining and visualizing deep learning-driven stock market prediction* (arXiv preprint 1709.01574). https://doi.org/10.48550/arXiv.1709.01574

Liu P., Yuan W., Fu J., Jiang Z., Hayashi H., Neubig G. (2023) Pre-train, prompt, and predict: A systematic survey of prompting methods in natural language processing. *ACM Computing Surveys*, 55(9), 195. https://doi.org/10.1145/3560815

Lou R., Zhang K., Yin W. (2023) *Is prompt all you need? No. A comprehensive and broader view of instruction learning* (arXiv preprint 2303.10475). https://doi.org/10.48550/arXiv.2303.10475

Mahmood A., Wang J., Yao B., Wang D., Huang C.M. (2023) *LLM-Powered Conversational Voice Assistants: Interaction Patterns, Opportunities, Challenges, and Design Guidelines* (arXiv preprint arXiv:2309.13879). https://doi.org/10.48550/arXiv.2309.13879

Meyer J.G., Urbanowicz R.J., Martin P.C., O'Connor K., Li R., Peng P.C., Gonzalez-Hernandez G., Bright T.J., Tatonetti N., Won K.J., Moore J.H. (2023) ChatGPT and large language models in academia: Opportunities and challenges. *BioData Mining*, 16(1), 20. https://doi.org/10.1186/s13040-023-00339-9

Seidenglanz R., Baier M. (2023) The Impact of Artificial Intelligence on the Professional Field of Public Relations/Communications Management: Recent developments and opportunities. In: *Artificial Intelligence in Public Relations and Communications: Cases, Reflections, and Predictions* (ed. A. Adi), Berlin: Quadriga University of Applied Sciences, pp. 14–25.

Solberg Søilen K. (2016) Economic and industrial espionage at the start of the 21st century – Status quaestionis. *Journal of Intelligence Studies in Business*, 6(3), 51–64.

Srivastava B., Lakkaraju K., Koppel T., Narayanan V., Kundu A., Joshi S. (2023) *Evaluating Chatbots to Promote Users' Trust – Practices and Open Problems* (arXiv preprint 2309.05680). https://doi.org/10.48550/arXiv.2309.05680

Tetlock P.E., Gardner D. (2016) *Superforecasting: The art and science of prediction*, New York: Random House.

Thoring K., Huettemann S., Mueller R.M. (2023) *The Augmented Designer: A Research Agenda for Generative AI-enabled Design*. Paper presented at the International Conference on Engineering Design (ICED23) 24–28 July 2023, Bordeaux, France. http://dx.doi.org/10.1017/pds.2023.335

Wang J., Liu Z., Zhao L., Wu Z., Ma C., Yu S., Dai H., Yang Q., Liu Y., Zhang S., Shi E., Pan Y., Zhang T., Zhu D., Li X., Jiang X., Ge B., Yuan Y., Shen D., Liu T., Zhang S. (2023a) *Review of large vision models and visual prompt engineering* (arXiv preprint 2307.00855). https://doi.org/10.48550/arXiv.2307.00855

Wang S., Scells H., Koopman B., Zuccon G. (2023b) *Can ChatGPT write a good boolean query for systematic review literature search?* (arXiv preprint 2302.03495). https://doi.org/10.48550/arXiv.2302.03495

Watson E., Viana T., Zhang S. (2023) Augmented Behavioral Annotation Tools, with Application to Multimodal Datasets and Models: A Systematic Review. *AI*, 4(1), 128–171. https://doi.org/10.3390/ai4010007

Yeadon W., Hardy T. (2023) *The Impact of AI in Physics Education: A Comprehensive Review from GCSE to University Levels* (arXiv preprint 2309.05163). https://doi.org/10.1088/1361-6552/ad1fa2

Zhang C., Wang W., Pangaro P., Martelaro N., Byrne D. (2023) Generative Image AI Using Design Sketches as Input: Opportunities and Challenges. In: *Proceedings of the 15th Conference on Creativity and Cognition,* New York: Association for Computing Machinery, pp. 254–261. https://doi.org/10.1145/3591196.3596820

The AI-Driven Transformative Potential of the Gaming Industry for Economy and Society

Tee Yi Qin

Undergraduate Student, Faculty of Technology Management and Business, pyteeyiqin@gmail.com

Nor Hazana Abdullah

Director, Centre for Leadership and Competence, hazana@uthm.edu.my

Universiti Tun Hussein Onn Malaysia, 86400 Batu Pahat, Johor, Malaysia

Natrah Mohd Emran

Expert, natrah@might.org.my

Malaysian Industry-Government Group for High Technology, 63000, Cyberjaya, Selangor, Malaysia

Abstract

Computer game production has long transcended the entertainment industry to become a complex, high-tech, innovative, highly profitable field with transformative potential for other sectors. It synthesizes technical and humanities disciplines such as artificial intelligence (AI), virtual reality, behavioral psychology, cognitive science, design, agent-based modeling, scenario planning, Foresight, complex systems science, and others. The paper explores the prospects of expanding this interdisciplinary field through the application of more sophisticated technologies, including AI algorithms. Foresight methodology was used, including such tools as horizon scanning, analysis of scientific, technological, political, economic and value factors, assessment of effects and uncertainty, as well as expert surveys. The collected data set formed the basis for four scenarios for the industry in Malaysia over the next ten years. This study contributes to informing policy rationale for the use of AI for game development for various purposes, including strategic planning practices.

Introduction

While formally belonging to the entertainment industry, the computer games industry has reached a new level in the process of ongoing profound transformation. Today it is a high-tech and highly profitable sector that helps solve a wide range of serious problems. The ideas and developments emanating from here continue to transform many areas of the economy and public life. Models of the metaverse and virtual currencies were born here, and great development potential remains through the integration of new technical and humanitarian areas, such as virtual reality, behavioral psychology, cognitive science, design, agent-based modeling, and scenario planning. Particularly significant transformation processes in this sector, as in many others, are associated with the further development of artificial intelligence (AI), the increasingly complex algorithms of which open up a wide range of new opportunities.

The leaders in the described process include the USA, China, Great Britain, Japan and some other countries in Europe and Asia. Thus, the Netherlands is a leader in the development of serious educational games related to the management of systems from local to global levels, in such areas as water resources (den Haan et al., 2020), infrastructure, transport (Duffhues et al., 2014), energy (Hettinga et al., 2020) and agriculture[1]. In Japan, gamification has become an integral part of annual nationwide exercises to prepare for rapid response to natural disasters[2].

The global volume of this industry is expected to reach $282.3 billion by the end of 2024, with the largest revenue coming from China ($94.49 billion). By 2027, its total turnover will increase to $363.2 billion (an annual increase of 8.76%), and the total number of users will be 1.472 billion people.[3]

Such dynamics stimulate the development of related areas, such as e-sports[4]. In 2023, the size of the global market in this area was estimated at $1.72 billion. It is predicted that this year its value will approach $2.06 billion, and by 2032 it will grow to $9.29 billion (average annual growth rate during 2024 –2032 will be 20.7%). Market growth is influenced by trends such as an increase in the frequency of live broadcasts of cyber tournaments, an increase in viewer interest, and increased investment in e-sports infrastructure. Universities view esports as a tool for developing specific professional skills in students, offering special educational programs[5]. The synthesis of virtual and physical reality with artificial intelligence (AI) in computer games, every year expands the possibilities of enriching the gaming experience (Tang et al., 2020). Moving games to mobile platforms has made them accessible and convenient for more users.

The role of serious games aimed at developing professional skills in education, healthcare, and management is increasing. The effectiveness of educational games (to acquire new skills and behavioral patterns) is enhanced by the dynamic response of AI algorithms to user actions, which is expressed in the behavior of smart characters that adapt to the player's learning style and thinking (Tang et al., 2020; Fairclough et al., 2002; Shi et al., 2023; Waltham, Moodley, 2016). Advanced AI-based analytics improves the quality of assessment of the educational process. With the increasing use of AI in the development of different types of games, there are prospects for the development of expanded skills and competencies in many disciplines. Considering their real and potential effects, a deep analysis of the fundamentals of AI, an understanding of the development processes of the corresponding systems, and an assessment of the ethical aspects of their use are necessary.

In general, a vast amount of literature is devoted to the issues of game development as such and the areas of their application. Our scanning of international scientific databases revealed over 3,800 such publications over the past 10 years. However, only a small number of works are devoted to the use of AI in this process.

Our article contributes to filling the corresponding gap. The main directions of using AI in the development of the gaming industry are considered in relation to the context of Malaysia, and four alternative development scenarios have been developed until 2032.

Literature review

The production of computer games began in the 1950s. and over time has grown into the most profitable segment in the global entertainment industry. The connection between AI and games can be traced back to the appearance of the first chess program. The quest to create AI capable of winning strategy games against high-end players has

---

[1] https://agriculture.newholland.com/en-gb/europe/new-holland-world/farming-simulator, accessed 05.06.2024.

[2] https://www.gfdrr.org/sites/default/files/publication/learning-from-disaster-simulation-drills-japan-report.pdf, accessed 09.04.2024.

[3] https://www.statista.com/outlook/dmo/digital-media/video-games/worldwide, accessed 03.12.2024.

[4] https://www.fortunebusinessinsights.com/esports-market-106820, accessed 03.07.2024.

[5] For example, Syracuse University University, USA) announced a new course dedicated to eSports in 2023.

spurred research, which in turn has led to significant advances in game design. AI technologies have revolutionized various aspects of game creation, from intelligent character generation and context-sensitive content to adaptive game mechanics and sophisticated analytics. Gaming companies see the benefits of AI, particularly in terms of opportunities to improve gaming experiences and save costs. Its application areas include, for example, improving visual effects, increasing their realism, dynamic content creation, balancing gameplay difficulty, and generating intelligent characters. Using AI in game design simplifies the development process, improves animation quality, and improves the efficiency of level design and content creation. The use of AI algorithms allows players to have a more immersive and dynamic gaming experience. AI-powered systems can adapt to the behavior of specific players, offer personalized challenges and increase engagement. The emergence of virtual and augmented reality, other immersive technologies, and their adaptation to mobile platforms will radically transform this area and open up vast opportunities for both developers and users.[6] The role of games itself has expanded, going far beyond the scope of entertainment purposes - they perform various complex tasks, penetrating into the field of education, business, management, medicine, energy, etc.

In the study (Bharathi et al., 2024) explored opportunities to improve educational programs in a new context based on AI. In this regard, significant attention is paid to business simulation games, which are recognized by an increasing number of experts as an effective practice-oriented tool for interactive education. They are increasingly used by universities and companies to make decisions and develop strategies. Along with AI, adaptation to mobile platforms and cloud computing make a certain contribution to their improvement. An attractive, motivating atmosphere is created that enhances cognitive processes and improves the quality of information absorption due to the effect of complete immersion. Game-based learning creates opportunities to practice project management concepts in a simulated, safe environment, promoting active engagement, developing critical thinking, problem-solving, collaboration and creativity skills (Jahan Tumpa et al., 2024).

The game approach is becoming widespread in STEM education (Gao et al., 2020). New research is revealing the pros and cons of integrating games into specific disciplinary contexts, contributing to a growing understanding of their potential for the educational field.

The connection between games and cognitive science and strategic thinking

The impact of various game genres on the cognitive functions of the brain, their contribution to the development of complex competencies and the improvement of strategic thinking has been the subject of numerous studies (Ghasemi et al., 2024). Differences in cognitive abilities lead to individual differences in working memory functions, visual perception, and reaction speed. As a result, the variety of behavioral models that determine attitudes towards risk, uncertainty, ambiguous, complex and confusing situations is expanding (Frederick, 2005). New developments allow the creation of increasingly advanced games aimed at increasing the productivity of strategic planning in business, the military sector, medicine, ecology and other areas (Bellotti et al., 2014).

The synthesis of such subject areas as game theory, cognitive psychology and systems thinking helps to reveal the nature of strategic thinking and identify effective tools for its development. Based on the differences in cognitive functions and the variety of behavioral patterns, developers face a difficult task - using AI to create gaming algorithms that adapt to the specifics of a particular user.

Business simulation games create an experimental reality where you can plan projects, implement them in roadmaps and experience the consequences of mistakes, gaining valuable experience (Dantas et al., 2004). An engaging, immersive gaming environment helps reinforce the right or wrong steps taken (Sanzana et al., 2024), key entrepreneurial skills, communication, problem solving, resource management, etc. are developed (Shabbir, Pallares-Venegas, 2024).

Recent research suggests the integration of serious games into soft skills development programs. With their help, employees are trained in diverse communication (Sutil-Martín, Otamendi, 2021). A number of universities have created gamified virtual biology and chemistry laboratories, allowing students to practice dangerous experiments without risk (Sanzana et al., 2024). Educational games significantly improve problem-solving skills by identifying hazards early and taking preventive action (Solinska-Nowak et al., 2018). Based on the understanding that games should reflect complex real-world environments with emergent behavior, land use simulations have been developed (Bishop et al., 2009), energy policy (Dolin, Susskind, 1992) and water and climate change management (Vervoort et al., 2022; Zhou, Mayer, 2017).

---

[6] https://techcrunch.com/2015/10/31/the-history-of-gaming-an-evolving-community/, accessed 04.17.2024.

Business games synthesize the modeling of system dynamics and agent behavior (Alessi, Kopainsky, 2015; Le Page et al., 2012; Smajgl et al., 2015), dynamic interactions between elements of complex systems are displayed, which makes it possible to anticipate the effects of feedback and develop preventive measures (Alessi, Kopainsky, 2015). A special genre of games has emerged for proactive management (*anticipatory games)*, focused on the formation of a preferred future within the framework of scenario planning (Vervoort, Gupta, 2018).

They offer unique opportunities to create and experiment with new systems of governance, including the creation of rules and institutions, the distribution of roles in dynamic contexts (Vervoort et al., 2022). For example, there are adaptations of popular Sim games City and Minecraft, which allow you to reproduce in the digital environment different development scenarios for cities of the future[7]. Various game theory heuristics are used as objects of political debate (Bekius et al., 2018).

Difficulties in developing computer games and the contribution of AI to overcoming them

Creating computer games requires a wide range of skills from different disciplines, particularly a combination of technological and artistic abilities (Hodgson, Briand, 2013). As gaming companies grow, the need for effective methods to manage the development process and its high-tech components increases (Kanode, Haddad, 2009). When creating complex software, problems often arise related to violation of the planned deadlines for project implementation, primarily due to the initial underestimation of the expected time *costs* (in 65% of cases) (Petrillo et al., 2008). In the professional environment, the practice of constant rush jobs in the development of games and other software is widely discussed, and their reasons are analyzed (Dyer-Witheford, De Peuter, 2006; Peticca-Harris et al., 2015). The successful implementation of projects is also influenced by the quality of communication between members of an interdisciplinary team, the provision of which is particularly difficult. To develop complex educational games, in most cases it is necessary to select the appropriate tools, documentation and algorithms for AI, animation creation, rendering and learning analytics (Tamla et al., 2019).

In psychology, there are biofeedback mobile apps and serious games to help young people manage their anxiety and fears effectively, using AI to analyze user data and provide personalized feedback and recommendations (Almeqbaali et al., 2022). The AI can recognize the player's emotions and stress level and reduce psychological tension[8].

Adaptive AI systems evaluate player behavior and adjust the game difficulty in real time according to the player's preparedness. The result is that the game remains fun without being overly difficult[9]. The "engines" that provide support for various game attributes are critical. For example, games serve as an "assistant coach" for people undergoing medical rehabilitation. They are created taking into account the individual needs of patients, creating a motivational environment to achieve the required results (Ambros-Antemate et al., 2021). In games like this, increasing the adaptability of the algorithms can radically affect the recovery results. Therefore, the difficult task is to provide their automatic correction and a convenient interface for manual configuration (Smeddinck, 2020). For this purpose, dynamic complexity adjustment approaches have been developed (Dynamic Difficulty Adjustment (DDA), which increases player engagement by adapting game difficulty based on the player's performance. To automatically change the difficulty of the game depending on the level of the player, AI systems (for example, AlphaDDA) have been created, making the gameplay harmonious and attractive (Xue et al., 2017).

Research methodology

To solve the problem (expanding the base of empirical data on the use of AI in game development), an exploratory study was carried out using Foresight methods, including horizon scanning, STEEPV analysis and the development of scenarios for the next 5-10 years. The STEEPV method was used to analyze existing and potential problems and trends that could affect the economy and society as a whole. Six groups of factors were taken into account: social, technological, economic, environmental, political and value. In this way, a questionnaire was constructed and distributed to a target sample of game developers. Its structure is presented in table. 1. As of the first half of 2023, there were 86 game startups in Malaysia[10].

---

[7] http://www.edudemic.com/minecraftedu-and-simcityedu-blazing-trails-for-interdisciplinary-learning/, accessed 05.02.2024.

[8] https://safeinourworld.org/news/how-ai-and-biofeedback-are-helping-players-manage-stress-and-anxiety/#:~:text=By%20tracking%20the%20player's%20heart,symptoms%20of%20stress%20and%20anxiety, accessed 01.19.2024.

[9] https://www.gdgtme.com/features/ai-in-gaming-taking-video-games-to-the-next-level/, accessed 02.18.2024.

[10] https://tracxn.com/d/explore/gaming-startups-in-malaysia/__lrKvnVOpLT8CmWXvf1x5HSuJ4pbuDM-c7kHiPJ7NqMM/companies, accessed 03.09./2024.

Since exact data on the number of employees in each company was not available, we proceeded from a generalized conditional threshold - at least five specialists (general population of 430 people). After filtering it in accordance with the method described in (Krejcie, Morgan, 1970), the sample size was 205 respondents. 33 questionnaires were completed (response rate - 16.1%) and analyzed using Microsoft Excel.

Secondary data was extracted from periodicals, online publications and dissertations relevant to the research topic and was not limited to Malaysian ones. The collected unstructured information was filtered to extract meaningful information.

Table 1. **Structure of the Questionnaires**	
Section	Items
A	Demographics of the respondents
B	The impact of drivers towards the AI in gaming development.
C	The uncertainty of drivers towards the AI in gaming development.
Source: auhtors.	

Results

The accumulated array of information became the basis for assessing the effect and uncertainty and constructing scenarios. Subsequent analysis revealed two underlying factors that lead to the greatest impact and greatest uncertainty when using AI. The effect-uncertainty matrix presented in Fig. 1 served as a framework for developing four alternative scenarios for the use of AI in the gaming industry over the next five to ten years. To fill them with content, we used the results of the STEEPV analysis, which identified eight key factors reflected in Table 2. The information collected is intended to enrich the evidence base for developing a holistic and informed approach to scientific and innovation policy in relation to the gaming industry.

The characteristics of the sample of respondents are presented in Table. 3, and the average values of the assessment of answers to the questions are in table. 4. According to respondents, factors related to intellectual property rights for AI content produce the greatest effect, and the greatest uncertainty is caused by technical problems of AI algorithms. Therefore, intellectual property rules require further analysis and refinement to protect the rights of developers. The importance of this aspect in the gaming industry has been noted in a number of sources. Key legal issues have been identified, in particular, the need to protect against game cloning[11]. The fact that for Malaysian engineers the highest level of uncertainty is associated with technical problems of AI algorithms reflects their current level of knowledge in the field.

In Fig. 2, the red circle highlights the factors responsible for the maximum magnitudes of effect and uncertainty, indicated by codes D5 ("Game-play and immersion") and D6 "Technical problems of AI algorithms." They became the basis for scenario analysis.

Scenarios for the future use of AI for game development

The scenario matrix is based on two factors that received maximum ratings from respondents: "Technical challenges of AI algorithms" and "Gameplay and immersion" (Figure 3).

Scenario 1 "Dynamic game environment". Recognized as the most preferred option, as it combines the low level of technical problems of AI algorithms with a high degree of immersion in the gameplay and a high-quality gaming experience. In this scenario, AI is used by most game developers to create the most dynamic gaming environment possible. AI algorithms will take the gaming industry to a new level of development, expanding opportunities for user engagement. The use of AI is ushering in a new era with an unprecedented quality of gaming experience[12]. Increasing the complexity of character behavior, procedural content creation, and game balancing combine to create a game world that is both complex and interesting for users. AI-powered analytics allows developers to study player behavior to create games that automatically adapt to different gaming styles and preferences.

Scenario 2 "Long game development cycle." Has both positive and negative aspects. The upside is that a long development cycle can ensure polished, polished games are created. Thus, the famous game "The Last Guardian" has been in development for eight years. Such a protracted process does not have one obvious reason; rather, it should be said that there are a number of interrelated problems. Among the factors that slowed down work were the departure of key studio employees, conflicts with the publisher (Sony) and other problems[13]. Despite

---

[11] https://www.qualityoracle.com/intellectual-property-rights-in-the-gaming-industry/#:~:text=Under%20IP%20protection%2C%20developers%20will,and%20sale%20of%20said%20games, accessed 04.18.2024.

[12] https://ilogos.biz/the-role-of-ai-in-game-development/#:~:text=Impact%20of%20AI%20in%20Gaming&text=This%20technological%20advancement%20has%20allowed,and%20challenging%20environment%20for%20players, accessed 05.05.2024.

[13] https://www.dualshockers.com/games-with-longest-development-times/#8-8-ultima-ix-ascension-five-years, accessed 02.14.2024.

Figure 1. **Impact-Uncertainty Matrix**

Source: auhtors.

Table 2. **Drivers Related to Merged Issues and Challenges**

1. Data Security and Privacy Concerns
- Data misuse or unauthorized access and theft
- Lack of transparency and responsibility
- Information withholding
- Privacy challenges

2. Ethical Considerations and Responsibility
- Ethical concern
- Ethical framework
- AI ethics
- Responsibility for harmful content or biased algorithmic outputs
- Mitigation of ethical risks
- Ownership and control of affective models
- Stereotypical portrayals of women
- Encouragement of violent behavior
- Safety and well-being of participants
- Trustworthiness

3. Ownership and Intellectual Property of AI-developed content
- Attribution of authorship and copyright concerns
- Patent protection and patentability
- Challenges in ownership, transparency, and responsibility
- Absence of comprehensive frameworks for ownership
- Ownership issues, data security, and user privacy

4. AI-driven Gaming Innovation
- AI in game-based learning
- AI integration into games
- Revolutionize the gaming experience
- Advanced AI models
- AI-generated content
- Shifting to utilizing neural networks

5. Gameplay Experience and Immersion
- Addictive tendencies
- Enjoyable and immersive gameplay experience
- Challenge for fair gameplay
- AI-generated content for engaging and human-like gameplay
- Automatic level generation
- Addressing sequential decision-making challenges

6. Technical Hurdles of AI algorithm
- AI explanation
- Limited tools
- Technical hurdles or constraints
- Uncertainty surrounding the opponent's decision
- Black-box nature of games
- Lack of transparency and predictability
- Addressing sequential decision-making challenges

7. Competitive Game Innovation
- Competitive environment for players
- Increasing player base
- AI voice recognition and perspective plug-in
- AI-generated engaging and human-like gameplay

8. Competitive Gaming Industry Environment
- Mounting competition among game developer
- Rapid growth of online gaming

Source: auhtors.

this "The Last Guardian" was successfully launched into the market and received mostly positive reviews. The disadvantages of a protracted development process include lost market opportunities or changed user preferences. What is considered innovative at the beginning of the cycle may lose relevance by the time it ends, and the risks of falling behind competitors' increase. Developers will have to invest more time and resources into the project with no guarantee of profit[14]. Thus, despite the complex technical problems of AI algorithms, this scenario also seems acceptable provided that players will receive a quality gaming experience through deep immersion.

Scenario 3: Dominance of technological complexity. It is assumed that when combined Due to significant problems with AI algorithms and a low level of immersion in the gameplay, developers will have to pay excessive attention to technical aspects. This can lead to the loss of consumers who are interested not so much in technological innovation as in the attractiveness of the process. Over-reliance on technological complexity can result in losing the immersion and engaging gaming experience that players have come to expect. The risks of losing such attributes that are responsible for interest in the game, such as an exciting plot, a detailed game world and an intuitive interface, are increasing. Consequently, the likelihood of this scenario being realized may be low, since it depends on the balance between technological innovation and gameplay, and the passion for improving AI algorithms can upset it.

Scenario 4: Monotonous gameplay. In a gaming context, monotony means that players have to deal with a limited standard set of tasks, missions, or quests. If AI algorithms lack complexity and the ability to create game challenges, the process becomes predictable and repetitive. Characters con-

Figure 2. **Impact-Uncertainty Analysis**

Source: auhtors.

---
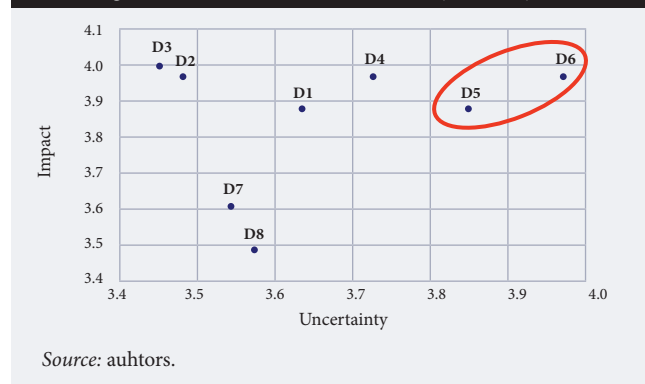
[14] https://www.gamedeveloper.com/business/the-risks-of-long-term-game-development, accessed 05.07.2024.

Table 3. **Demographics of respondents**

Category	Frequency	Percentage (%)
Gender		
Male	22	66.7
Female	11	33.3
Age		
18-24 years old	10	30.3
25-34 years old	11	33.3
35-44 years old	9	27.3
45 years old and above	3	9.1
Place of work		
Game development companies *	13	39.4
University **	2	6.1
Freelancing	10	30.3
Prefer not to say	8	24.2
Current job role		
Game designer	8	24.2
Game programmer	10	30.3
Producer	1	3. 0
Artist/animator	9	27.3
Writer / Storyteller	2	6.1
Tools Developer	3	9.1
Busy mode		
Student	7	21.2
Full time employed	14	42.4
Part-time employed	6	18. 2
Self-employed	6	18. 2
Years of experience in game development		
Less than 1 year	5	15.2
1-3 years	14	42.4
4-6 years	5	15.2
7-10 years	5	15.2
More than 10 years	4	12.0
Size of the development team		
Individual developer	12	36. 4
Small team (2-10 people)	11	33.3
Medium team (11-50 people)	7	21.2
Large team (51+ people)	17	9. 1
Priority game platform focus		
PC	16	48.5
Console	2	6.1
Mobile	9	27.3
Virtual Reality	4	12.1
Augmented Reality	2	6.1
Familiarity with AI in gaming		
Very familiar	6	18.2
Somewhat familiar	19	57. 6
Not very familiar	5	15. 2
Not at all familiar	3	9.1
Integration of AI in current projects		
Actively integrating AI features	8	24.2
Considering integrating AI features	11	33.3
Not currently integrating AI features	8	24.2
No plans to integrate AI features	6	18.2

* Gameka, Knowles, Double 11, Dandelion Studio, Quurk, AC, HY Building, KPM, Alchymy Creative, Manson Games, Kayangan, PlayStation, Illuminative (each by alone representative).
** UOW Malaysia, Universiti Tunku Abdul Rahman (each by alone representative).

Source: compiled by the authors.

Table 4. **MEAN score of Impact and Uncertainty drivers**

Code	Drivers	Mean	
		Impact	Uncertainty
D1	Data security and privacy concerns	3.879	3.636
D2	Ethical consideration and responsibility	3.970	3.485
D3	Ownership and intellectual property of AI-developed content	4.000	3.455
D4	AI-driven gaming innovation.	3.970	3.727
D5	Gameplay experience and immersion	3.879	3.848
D6	Technical hurdles of AI algorithm	3.970	3.970
D7	Competitive game innovation	3.606	3.545
D8	Competitive gaming industry environment	3.485	3.576

Source: auhtors.

Figure 3. **Development of Four Alternative Scenario**
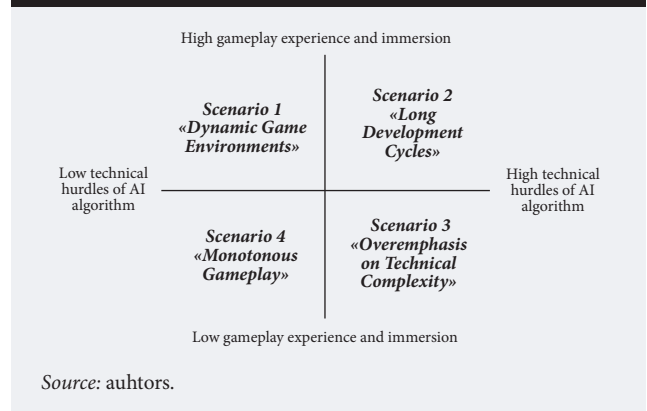
Source: auhtors.

trolled by the AI exhibit monotonous behavior with minimal differences in reactions or strategic decisions, resulting in a loss of interest in the game. This scenario could be the worst. If Malaysian game developers ignore solving the complex technological problems of AI algorithms, gameplay immersion will be low and the gaming experience will be substandard. Resistance to using AI for game development will increase.

Conclusion

The gaming industry is considered a high-tech, innovative and highly profitable sector with a high potential for impact on the economy and society as a whole. These opportunities can be unlocked with the help of AI and other advanced technologies. It is of interest to assess the readiness of gaming product developers to implement more complex and adaptive AI algorithms.

For the first time in the Malaysian context, the article examines the prospects for the use of AI in this area. A comprehensive analysis of the factors determining them was carried out, combining a study of the literature and a survey of experts. Based on the two identified key drivers associated with the greatest impact and uncertainty, four alternative scenarios are developed. The "Dynamic Gaming Environment" scenario is considered the most preferable, since it is the combination of the lack of complexity with the implementation of AI algorithms with a focus on enriching the gaming experience of users that opens up the widest possible range of opportunities for the gaming industry.

Like any study, the analysis we present has its limitations. This is only the first attempt to provide an empirical basis for understanding the specific challenges and opportunities that the gaming industry may face as it implements AI technologies. Another limitation is the size and composition of the sample. Despite this, the collected data set turned out to be quite informative, which made it possible to solve the research problem.

Several recommendations can be offered to overcome these limitations. First of all, in future research it would be advisable to expand the methodology and conduct in-depth interviews to better understand the relevant topics and other issues not covered in the literature. The presented research can serve as a starting point for assessing the dynamics of the future use of AI by game developers. In addition, scholars or policy makers can use the results of this work to assess the impact and uncertainty of AI use in Malaysia. This will help enhance the positive effects of using such technologies for game development and mitigate the negative consequences. It is clear that, despite the widespread use of AI in game development noted in many studies, concerns about this remain. In general, games, especially those based on AI, expand the impact on the development of different areas, as well as complex and valuable skills in users. There is a need to find the right balance between creating innovation and using it responsibly to ensure gaming is safe, inclusive and beneficial for people of all ages.

References

Alessi S., Kopainsky B. (2015) System dynamics and simulation/gaming: Overview. *Simulation and Gaming*, 46 (3–4), 223–229. https://doi.org/10.1177/1046878115596390

Almeqbaali M., Ouhbi S., Serhani M.A., Amiri L., Jan R.K., Zaki N., Sharaf A., Al Helali A., Almheiri E. (2022) A Biofeedback-Based Mobile App With Serious Games for Young Adults With Anxiety in the United Arab Emirates: Development and Usability Study. *JMIR Serious Games*, 10(3), e36936. https://doi.org/10.2196/36936

Ambros-Antemate J.F., Beristain-Colorado M.D.P., Vargas-Treviño M., Gutiérrez-Gutiérrez J., Hernández-Cruz P.A., Gallegos-Velasco I.B., Moreno-Rodríguez A. (2021) Software Engineering Frameworks Used for Serious Games Development in Physical Rehabilitation: Systematic Review. *JMIR Serious Games*, 9(4), e25831. https://doi.org/10.2196/25831

Bekius F., Meijer S., de Bruijn H. (2018) Collaboration patterns in the Dutch railway sector: Using game concepts to compare different outcomes in a unique development case. *Research in Transportation Economics*, 69, 360–368. https://doi.org/10.1016/j.retrec.2018.06.011

Bellotti F., Berta R., De Gloria A., Lavagnino E., Antonaci A., Dagnino F., Ott M., Romero M., Usart M., Mayer I.S. (2014) Serious games and the development of an entrepreneurial mindset in higher education engineering students. *Entertainment Computing*, 5(4), 357–366. https://doi.org/10.1016/j.entcom.2014.07.003

Bharathi G.P., Chandra I., Sanagana D.P.R., Tummalachervu C.K., Rao V.S., Neelima S. (2024) AI-driven adaptive learning for enhancing business intelligence simulation games. *Entertainment Computing*, 50, 100699. https://doi.org/10.1016/j.entcom.2024.100699

Bishop I.D., Stock C., Williams K.J. (2009) Using virtual environments and agent models in multi-criteria decision-making. *Land Use Policy,* 26(1), 87–94. https://doi.org/10.1016/j.landusepol.2008.01.010

Dantas A.R., de Oliveira Barros M., Werner C.M.L. (2004) *A simulation-based game for project management experiential learning.* Paper presented at the International Conference on Software Engineering and Knowledge Engineering (SEKE) 2004, June 20–24, Banff, Canada.

den Haan R.J., van der Voort M.C., Baart F., Berends K.D., van den Berg M.C., Straatsma M.W., Geenen A.J.P., Hulscher S.J.M.H. (2020) The Virtual River Game: Gaming using models to collaboratively explore river management complexity. *Environmental Modelling & Software,* 134, 104855. https://doi.org/10.1016/j.envsoft.2020.104855

Dolin E.J., Susskind L.E. (1992) A role for simulations in public policy disputes: The case of national energy policy. *Simulation & Gaming*, 23(1), 20–44. https://doi.org/10.1177/1046878192231003

Duffhues J., Mayer I.S., Nefs M., van der Vliet M. (2014) Breaking barriers to transit-oriented development: Insights from the serious game SPRINTCITY. *Environment and Planning B: Urban Analytics and City Science*, 41(5), 770–791. https://doi.org/10.1068/b39130

Dyer-Witheford N., De Peuter G.S. (2006) "EA Spouse" and the crisis of video game labour: Enjoyment, exclusion, exploitation, exodus. *Canadian Journal of Communication,* 31(3), 599–617. https://doi.org/10.22230/cjc.2006v31n3a1771

Fairclough C., Fagan M., Mac Namee B., Cunningham P. (2002) *Research directions for AI in Computer Games* (Computer Science Technical Report TCD-CS-2001-29), Dublin: Trinity College. http://www.tara.tcd.ie/handle/2262/13098, accessed 21.04.2024.

Frederick S. (2005) Cognitive reflection and decision making. *Journal of Economic Perspectives,* 19(4), 25–42. https://doi.org/10.1257/089533005775196732

Gao F., Li L., Sun Y. (2020) A systematic review of mobile game-based learning in STEM education. *Educational Technology Research* and *Development*, 68, 1791–1827. https://doi.org/10.1007/s11423-020-09787-0

Georghiou L. (2001) *Third generation foresight – integrating the socio-economic dimension* (NISTEP Report 77), Tokyo: NISTEP.

Ghasemi O., Abooyee M., Labafi S., Shirzad M. (2024) The role of video games in enhancing managers' strategic thinking and cognitive abilities: An experiential survey. *Entertainment Computing,* 50, 100694. https://doi.org/10.1016/j.entcom.2024.100694

Giannakos M., Voulgari I., Papavlasopoulou S., Papamitsiou Z., Yannakakis G. (2020) Games for artificial intelligence and machine learning education: Review and perspectives. In: *Non-Formal and Informal Science Learning in the ICT Era* (ed. M. Giannakos), Singapore: Springer, pp. 117–133. https://doi.org/10.1007/978-981-15-6747-6_7

Hettinga S., Boter J., Dias E., Fruijtier S., de Vogel B., Scholten H. (2020) Urban energy transition in a gaming context: The role of children. *Land Use Policy*, 111, 104903. https://doi.org/10.1016/j.landusepol.2020.104903

Hodgson D., Briand L. (2013) Controlling the uncontrollable: "Agile" teams and illusions of autonomy in creative work. *Work, Employment & Society*, (2), 308.

Jahan Tumpa R., Ahmad T., Naeni L.M., Kujala J. (2024) Computer-based games in project management education: A review. *Project Leadership and Society*, 5, 100130. https://doi.org/10.1016/j.plas.2024.100130

Kanode C.M., Haddad H.M. (2009) Software Engineering Challenges in Game Development. Paper presented at the 2009 Sixth International Conference on Information Technology, Las Vegas, NV, USA 27–29 April 2009. https://doi.org/10.1109/itng.2009.74

Krejcie R.V., Morgan D.W. (1970) Determining sample size for research activities. *Educational and Psychological Measurement,* 30(3), 607–610. https://doi.org/10.1177/001316447003000308

Le Page C., Becu N., Bommel P., Bousquet F. (2012) Participatory agent-based simulation for renewable resource management: The role of the cormas simulation platform to nurture a community of practice. *Journal of Artificial Societies and Social Simulation,* 15(1), 10. https://doi.org/10.18564/jasss.1928

Papastergiou M. (2009) Digital game-based learning in high school computer science education: Impact on educational effectiveness and student motivation. *Computers & Education*, 52(1), 1–12. https://doi.org/10.1016/j.compedu.2008.06.004

Peticca-Harris A., Weststar J., McKenna S. (2015) The perils of project-based work: Attempting resistance to extreme work practices in video game development. *Organization,* 22(4), 570–587. https://doi.org/10.1177/1350508415572509

Petrillo F., Pimenta M., Trindade F., Dietrich C. (2008) *Houston, we have a problem. A survey of actual problems in computer games development.* Paper presented at the the 2008 ACM symposium on Applied computing. https://doi.org/10.1145/1363686.1363854

Reckien D., Eisenack K. (2013) Climate change gaming on board and screen: A review. *Simulation & Gaming,* 44 (2–3), 253–271. https://doi.org/10.1177/1046878113480867

Reeves B., Malone T.W., O'Driscoll T. (2008) Leadership's online labs. *Harvard Business Review*, 86, 58–66.

Sanzana M. R., Abdulrazic M. O., Wong J. Y., Yip C.-C. (2023). Gamified virtual labs: shifting from physical environments for low-risk interactive learning. *Journal of Applied Research in Higher Education,* 16(1), 208–221. https://doi.org/10.1108/JARHE-09-2022-0281

Sanzana M.R., Abdulrazic M.O.M., Wong J.Y., Yip C.C. (2024) Personnel Training for Common Facility Management Issues in Thermal-Energy-Storage Chiller Plant using a Serious 3D Game. *Simulation & Gaming,* 55(2), 224–248. https://doi.org/10.1177/10468781241232594

Shabbir M.S., Pallares-Venegas E. (2024) Influences of entrepreneurship skills and universities on the promotion of entrepreneurial intentions of students; mediating role of business simulation games. *On the Horizon*, 32(1), 1–14. https://doi.org/10.1108/OTH-10-2022-0062

Shi Y., Li H., Fu X., Luan R., Wang Y., Wang N., Sun Z., Niu Y., Wang C., Zhang C., Wang Z.L. (2023) Self-powered difunctional sensors based on sliding contact-electrification and tribovoltaic effects for pneumatic monitoring and controlling. Nano *Energy,* 110, 108339. https://doi.org/10.1016/j.nanoen.2023.108339

Silva L., Mousavidin E. (2015) Strategic Thinking in Virtual Worlds: Studying World of Warcraft. Computers in Human Behavior, 46, 168–180. https://doi.org/10.1016/j.chb.2014.12.047

Smajgl A., Ward J.R., Foran T., Dore J., Larson S. (2015) Visions, beliefs, and transformation: Exploring cross-sector and transboundary dynamics in the wider Mekong region. *Ecology and Society,* 20(2), 15. http://dx.doi.org/10.5751/ES-07421-200215

Smeddinck J.D. (2020) *Human-Computer Interaction with Adaptable & Adaptive Motion-based Games for Health* (ArXiv Paper abs/2012.03309). https://doi.org/10.48550/arXiv.2012.03309

Solinska-Nowak A., Magnuszewski P., Curl M., French A., Keating A., Mochizuki J., Jarzabek L. (2018) An overview of serious games for disaster risk management – Prospects and limitations for informing actions to arrest increasing risk. *International Journal of Disaster Risk Reduction,* 31, 1013–1029. https://doi.org/10.1016/j.ijdrr.2018.09.001

Sutil-Martín D.L., Otamendi F.J. (2021) Soft Skills Training Program Based on Serious Games. *Sustainability,* 13(15), 8582. https://doi.org/10.3390/su13158582

Tamla P., Böhm T., Gaisbachgrabner K., Mertens J., Hemmje M., Fuchs M. (2019) Survey: Software search in serious games development. *CEUR Workshop Proceedings*, 2348, 155–166.

Tang C., Wang Z., Sima X., Zhang L. (2020) *Research on Artificial Intelligence Algorithm and Its Application in Games*. Paper presented at the 2nd International Conference on Artificial Intelligence and Advanced Manufacture (AIAM). https://doi.org/10.1109/AIAM50918.2020.00085

Vervoort J., Gupta A. (2018) Anticipating climate futures in a 1.5°C era: The link between foresight and governance. *Current Opinion in Environmental Sustainability*, 31, 104–111. https://doi.org/10.1016/j.cosust.2018.01.004

Vervoort J., Mangnus A., McGreevy S., Ota K., Thompson K., Rupprecht C., Tamura N., Moossdorff C., Spiegelberg M., Kobayashi M. (2022) Unlocking the potential of gaming for anticipatory governance. *Earth System Governance,* 11, 100130. https://doi.org/10.1016/j.esg.2021.100130

Waltham M., Moodley D. (2016) *An Analysis of Artificial Intelligence Techniques in Multiplayer Online Battle Arena Game Environments*. Paper presented at the Annual Conference of the South African Institute of Computer Scientists and Information Technologists. https://doi.org/10.1145/2987491.2987513

West D.M., Allen J.R. (2023) *How artificial intelligence is transforming the world*, Washington, D.C.: Brookings Institute.

Wu J.S., Lee J.J. (2015) Climate change games as tools for education and engagement. *Nature Climate Change*, 5, 413–418. https://doi.org/10.1038/nclimate2566

Zhou Q., Mayer I.S. (2017) Models, Simulations and Games for Water Management: A Comparative Q-Method Study in the Netherlands and China. *Water,* 10(1), 10. https://doi.org/10.3390/w10010010

The Relationship between Corporate Political Strategy of Public Partnership and Corporate Investment

Lin Woon Leong[1]

Professor, School of Management and Marketing, linwoonleong@gmail.com

Kelvin Lee Yong Ming[1]

Senior Lecturer, School of Accounting and Finance, kelvinyongming.lee@taylors.edu.my

Pek Chuen Khee[1]

Associate Professor, School of Management and Marketing, eugene.pek@taylors.edu.my

Irfah Najihah Binti Basir Malan[2]*

Senior Lecturer, Faculty of Business and Management, irfah@uitm.edu.my

Ho Ree Chan[1]

Associate Professor, School of Management and Marketing, reechan.ho@taylors.edu.my

[1] Taylor's University, No. 1, Jalan Taylor's, 47500 Subang Jaya, Selangor, Malaysia

[2] Universiti Teknologi MARA (UiTM) Cawangan Melaka Kampus Bandaraya Melaka, 40450 Shah Alam, Selangor Darul Ehsan, Malaysia

Abstract

Companies are adopting a variety of strategies to reach new levels of development. Along with the course on self-sufficiency and risk management, many players consider a complex combination of strategic actions acceptable for themselves: they invest in political initiatives, expecting in the long term to receive government support in order to turn it into a "booster" for their own investment and innovation activity.

This article presents a detailed analysis of the impact of corporate political activity (CPA) on the formation of long-term technological and market advantages for business. This study is based on a sample of US-listed companies. The effects of the considered strategy for improving business performance appear to be ambiguous. To develop and clarify the results of previous studies, it is concluded that CPA brings tangible benefits to companies only up to a certain limit. The most significant benefits from the use of this tool, in addition to small companies, are derived by large players, which for one reason or another have been in a vulnerable position in terms of building capital. On the contrary, self-sufficient and stable business entities that have managed to accumulate a solid investment base should abandon CPA. Instead, they should focus on expanding their market presence and investing in research and development, which will provide more tangible returns than CPA.

Keywords: long-term strategies; technological potential; research and development; innovation; corporate political activity; corporate investment; uncertainty; quantile regression

* Corresponding author.

Introduction

Many companies, in an effort to increase sustainability, foster innovation and gain higher competitiveness, see partnership with governments as an effective tool in realizing these goals. By building up political capital, businesses discover certain advantages that would otherwise take a long time and be faced with great obstacles to achieve. Corporate political activity (CPA) has emerged as a prevalent strategy for firms in the United States and globally to exert influence over government policies, regulations, and overall performance (Ramesh, 2024; Slater et al., 2024). In the new context, it is often addressed by high-tech companies (Gomez et al., 2017; Guedhami et al., 2014). The practice of lobbying can be traced back to the early days of the American Revolution, and it was officially regulated in 1876 (Byrd, 1991). Since then, lobbying has experienced significant growth. According to the Center for Responsive Politics (CRP), in 2019, the United States had 11,890 lobbyists, and lobbying expenses escalated from $1.45 billion in 1998 to $3.5 billion. A considerable portion of lobbying funding can be attributed to businesses that extensively contribute to Political Action Committees (PACs).[1] In the 2019-2020 election cycle, Honeywell International, the National Beer Wholesalers Association, and the Sheet Metal, Air, Rail, and Transportation Union were the top contributors. It is important to note that CPA is not limited to the United States; many firms engage in political participation worldwide. Scholars have extensively documented the pervasive nature of corporate lobbying in regions such as the European Union (Massaro, 2019), South Korea (Lee et al., 2022), Japan (Romann, 2020), Jordan and Kuwait (Goldstraw-White, Martin, 2016), and Russia (Denisov, 2010). Therefore, it is evident that firms allocate significant resources to political activities and play prominent roles in the political landscape, both in the United States and globally.

Contemporary literature in economics and political science highlights the significant value attributed to CPA by businesses, with non-market strategies placing a strong emphasis on political engagements. However, existing research in this field often overlooks the empirical and theoretical aspects of businesses' political engagements. While scholars possess a good understanding of which firms engage in CPA and their motivations, the effectiveness of tactics and how CPA evolves over time and across different contexts remain uncertain (Getz, 1997). Despite the crucial role of CPA, empirical evidence regarding its impact on corporate investments is scarce, prompting scholars to call for further research to assist managers in making well-informed decisions about CPA.

Recent studies indicate that CPA plays a crucial role in firms' strategies for national competitiveness, and this rationale has been extended to the realm of corporate investment by various researchers (Xu, Yan, 2019; Alok, Ayyagari, 2020; Rudy, Cavich, 2020; Lin, 2019, 2020). Despite the highly regarded value of CPA for corporate investment, empirical findings in this area remain inconclusive and ambiguous (Lin, Si, 2010; Ramesh, 2024; Slater et al., 2024). Research indicates that firms with strong political connections are more likely to acquire resources, enhance learning, and improve overall performance (Hillman, 2005; Lin, 2019, 2020; Wu et al., 2013). However, other studies suggest either no impact or even a negative impact (Lin, 2019; Faccio, 2010; Fan et al., 2007). Changes in the political power structure can also exert adverse effects on corporate investments (An et al., 2016), particularly during periods of uncertainty such as elections or policy changes (Gulen, Ion, 2016). Notably, research indicates that CPA significantly influences the capital market, impacting various parameters such as market valuation (Faccio, 2010), cost of debt (Bliss, Gul, 2012), firm performance (Jackowicz et al., 2014; Lin et al., 2019), organizational governance (Fung et al., 2015), stock returns (Cooper et al., 2010), earnings persistence (Liu et al., 2018), crash risk (Piotroski et al., 2015), and mergers and acquisitions (Liou et al., 2021; Funk, Hirschman, 2017). Due to the knowledge gaps and diverse academic viewpoints regarding the importance of CPA, this study aims to fill the research gap by investigating the influence of CPA on corporate investment using new mathematical methods. Additionally, some studies suggest that the type of CPA matters, making it important to explore the topic comprehensively.

This study addresses the research gap concerning the correlation between CPA and corporate investment. The study contributes to the existing knowledge in three key ways. Firstly, it examines the positive impact of CPA on corporate investment within a politically stable environment, which has not been extensively explored in prior studies. Previous research suggests that CPA diminishes corporate investment during periods of political instability; however, we anticipate observing higher levels of corporate investment during more stable periods. Secondly, the study expands the current understanding of the association between CPA and various financial market outcomes such as profitability (Liu et al., 2018), stock returns (Goldman et al., 2009), firm performance (Jackowicz et al., 2014), and cost of debt (Bliss, Gul, 2012; Khaw et al., 2019) by incorporating the concept of corporate investment.

The literature on management strategy commonly recognizes two sources of endogeneity: unobservable heterogeneity and simultaneity. However, researchers often overlook the endogeneity resulting from past corporate investment, which in turn influences current values of CPA. Neglecting this endogeneity can have significant implications for the validity of any inferences drawn. Given the challenges associated with

---

[1] http://www.opensecrets.org, accessed 12.02.2024.

identifying exogenous instruments or natural experiments in different contexts, researchers often rely on panel data and fixed-effect estimates as an alternative approach. To ensure reliable and robust estimates, assuming that unobserved heterogeneity is fixed or time-invariant, this study employs a dynamic generalized method of moments (GMM) panel estimator to estimate the relationship between CPA and corporate investment.

The third contribution of this study lies in the use of quantile regression, which is a more appropriate technique than simple mean linear regression for analyzing the association between CPA and corporate investment. Mean linear regression focuses solely on the conditional mean, disregarding the entirety of the distribution of the dependent variable that is influenced by the independent variables. In contrast, quantile regression takes into account the distribution of the dependent variable and identifies variations in the relationship across different points in the distribution. This technique allows for coefficient estimations that consider the quantiles of the dependent variable, making it well-suited for exploring heterogeneous relationships within different percentile ranges of the dependent variable. Thus, we employ quantile regression to examine the relationship between CPA and corporate investment, aiming to uncover new insights in this domain (Galvao, 2011).

The structure of this study is organized into several sections. The first section discusses the theoretical framework, followed by a justification of the working hypotheses. The econometric technique used in the study is presented in the subsequent section, which includes a description of the empirical variables and a descriptive data analysis. The research findings are then presented and examined, followed by a final discussion and conclusion of the study in the last section.

Literature Review and Hypotheses Development

Corporate Political Activity

A meticulous examination of CPA reveals a multitude of significant challenges and limitations that impede our holistic understanding of its implications and outcomes (Ma, Xue, 2024; Sutton et al., 2021). Despite its escalating prevalence in contemporary business landscapes, the lack of a cohesive theory of political strategy and the varying explanations for firms' engagement in political activities pose formidable obstacles to fully apprehending the motivations and consequences of CPA (Lawton et al., 2013; Lux et al., 2011; Cooper et al., 2010; Hadani et al., 2017; Sutton et al., 2021). At the heart of the matter lies the potential for CPA to undermine democratic processes, effectively allowing firms endowed with substantial financial resources

to exert disproportionate influence over government policies and decisions. This engenders profound concerns about the integrity and inclusivity of the political system, alongside the looming specter of regulatory capture, where powerful corporations wield their clout to shape policies in their favor, often at the expense of broader societal interests (Hacker, Pierson, 2011; Bertrand, Perrin, 2024; Ramesh, 2024; Slater et al., 2024).

For instance, in the pharmaceutical industry, companies have been known to engage in extensive lobbying efforts to influence drug pricing policies and regulations. One notable example is the case of Mylan Pharmaceuticals, which faced significant public backlash after it increased the price of its life-saving EpiPen medication by over 500% over the course of a decade. Mylan's aggressive lobbying tactics and political contributions came under scrutiny, highlighting the potential negative consequences of corporate political influence on public health policies.[2]

Moreover, the impact of CPA on firm performance remains a contentious and inconclusive terrain. While certain studies suggest positive outcomes, such as heightened access to resources and bolstered competitive advantage stemming from political engagement, others unveil no discernible benefits or even signal negative effects (Shi et al., 2020). This variability in findings underscores the intricate interplay of contextual factors, the inherent challenge of disentangling the causal relationship between CPA and firm performance, and the manifold complexities inherent in gauging the efficacy of political activities (Hadani et al., 2017; Ramesh, 2024; Slater et al., 2024). Furthermore, the ethical ramifications of CPA loom large on the horizon. The blurred delineation between corporate interests and public welfare triggers fundamental queries concerning the legitimacy and transparency of corporate influence in political decision-making processes. It is incumbent upon us to subject the potential conflicts of interest, the ever-present risk of regulatory capture, and the broader societal implications of corporations leveraging CPA to advance their vested agendas to rigorous scrutiny (Anastasiadis et al., 2018).

The quest to deepen our comprehension of CPA necessitates a rigorous and expansive inquiry that adopts a critical lens and delves into the intricacies and power dynamics at play. This entails not only exploring the ethical dimensions and potential social disparities inherent in corporate political engagement but also scrutinizing the enduring societal ramifications. Additionally, the development of robust methodologies and rigorous analytical frameworks to evaluate the effectiveness and broader impact of CPA is imperative. Only through such endeavors can we illuminate stakeholders and guide the formulation of policies that prioritize transparency, accountability, and the broader public interest in political decision-making processes.

---

[2] https://www.cbsnews.com/news/epipen-price-hikes-add-millions-to-pentagon-costs /, accessed 18.02.2024.

Corporate Political Activity and Corporate Investments

The concept of political patronage (Shleifer, Vishny, 1994), introduces the idea that firms can gain favorable business advantages from the government through strategic political engagements. This involves firms leveraging their connections with influential politicians, often by contributing financially to political campaigns, in exchange for government support (Sutton et al., 2021). The theory posits that firms with promising growth prospects, which are largely driven by corporate investments, are more inclined toward engaging in CPA. These prospects act as indicators of a firm's growth potential and help mitigate uncertainties about future expansion. As such, firms may tailor their CPA strategies to not only pursue growth objectives but also to create a competitive moat against potential rivals and uncertainties, thus actively seeking political alliances.

Nevertheless, the repercussions of such political engagements necessitate a critical assessment. This entails evaluating potential market competition distortions, the fairness in the allocation of resources, and the likelihood of rent-seeking behaviors that could undermine societal welfare. A deeper investigation into the mechanisms and impacts of political patronage is essential, considering the efficacy of CPA in meeting growth objectives, the durability of political connections, and their enduring effects on firm performance and societal implications. Moreover, an analysis of the ethical dimensions and associated risks of political patronage could provide critical insights for policymakers and stakeholders intent on ensuring fair and transparent interactions between businesses and governments.

Recent research endeavors, exemplified by (Hart, 2001; Wang et al., 2018), have utilized the ratio of R&D expenditures to sales as a means to measure a firm's technological intensity and its propensity to engage in CPA. They suggest a positive association between R&D intensity and CPA engagement, indicating that technologically advanced firms may seek to maximize returns on their investments through strategic political activities (Gomez et al., 2017; Guedhami et al., 2014). Consequently, these firms might intensify their CPA efforts to preserve their political influence and sustain profitability, provided the benefits outweigh the costs.

This discourse suggests that firms with significant R&D investments, indicative of a strong emphasis on innovation, are likely to engage more actively in CPA. This strategic engagement is aimed at conserving political capital and enhancing financial performance. An empirical validation of this hypothesis could shed light on the complex interplay between R&D intensity, CPA, and firm outcomes.

Recent studies exploring the dynamic relationship between corporate strategies, political engagement, and financial outcomes provide valuable insights. For instance, some researchers have demonstrated a nuanced view of CPA, finding that firms' political contributions are closely linked to their market performance and the regulatory environment (Cooper et al., 2010; Sutton et al., 2021). This suggests that while CPA can offer advantages in terms of policy influence and regulatory outcomes, the benefits are contingent upon the firm's ability to navigate the political landscape effectively. Furthermore, the study (Hill et al., 2013) highlights the strategic considerations firms must weigh when engaging in CPA, emphasizing the importance of aligning political activities with overall business objectives to ensure long-term sustainability and growth.

Based on the discussion above and the insights from previous research, we propose the following hypothesis:

H1: Corporate Political Activity (CPA) has a positive relationship with corporate investment.

Corporate Political Activity and Corporate Investment in Low-Investment Firms

Recent research (Ozer, Markóczy, 2010; Ashyrov, Lukason, 2022) offers invaluable insights into the strategic maneuvers of small and medium-sized enterprises (SMEs) as they adeptly utilize CPA to navigate the intricate landscape of accessing external capital and fortifying their investment initiatives. SMEs endowed with robust political networks showcase a heightened capacity to surmount financial barriers and successfully procure external capital, thus effectively positioning themselves for sustainable growth and expansion (Brown et al., 2023). Furthermore, insights from Tyler et al. (2023) highlight the proactive engagement of politically connected SMEs in shaping regulatory environments to their advantage. By actively participating in political processes, these firms not only adeptly navigate bureaucratic hurdles but also gain invaluable insights into forthcoming policies and regulations, enabling them to adapt their investment strategies in anticipation of evolving market conditions. There is evidence that SMEs with well-established political ties are better positioned to capitalize on opportunities for securing debt financing, enabling them to pursue strategic investment initiatives and fuel their growth trajectory.

Based on these discussions, the following hypothesis is proposed:

Hypothesis H2: CPA has a positive relationship with corporate investment when the firm has a low investment level.

Corporate Political Activity and Corporate Investment in High-Investment Firms

The strategic choice perspective (Child, 1972) elucidates the multifaceted challenges encountered by organizations when making strategic decisions that profoundly impact their goals, technological frameworks,

and operational domains. This perspective posits that organizations possess the autonomy to deliberate and select adaptive responses to both internal and external stimuli. Despite the constraints imposed by external environments, large organizations wield considerable influence in reshaping their surroundings by actively manipulating and redefining objective aspects of their operating environments. Empirical research underscores the substantial impact of such organizations on local economies, attributing their significance to their heightened productivity levels and adept utilization of modern technologies. Furthermore, these entities typically exhibit accelerated growth trajectories and enjoy prolonged business survival rates in comparison to their small and medium-sized counterparts, rendering them less reliant on governmental assistance and demonstrating diminished reliance on CPA.

Expanding on this perspective, recent studies by Beugelsdijk and Cornet (2021) underscore the profound influence that large organizations exert on local economies, highlighting their role in driving productivity and technological advancement. Similarly, Bhagat and Bolton (2008) emphasize the accelerated growth trajectories of large organizations and their reduced dependence on governmental assistance, indicating their ability to navigate operational challenges without extensive reliance on corporate political activity.

Moreover, Hillman and Keim (2001) emphasize the importance of large organizations in effectively balancing market and non-market strategies to maintain competitiveness and foster sustainable growth. They argue that integrating robust strategies in both domains is imperative for achieving long-term success amid dynamic market landscapes.

On the topic of resource allocation and strategic decision-making, Bonardi (2003) suggests that large organizations often face challenges in effectively allocating resources between market and non-market strategies due to overlapping resource requirements. This highlights the complexity involved in optimizing resource utilization to achieve desired strategic outcomes.

Furthermore, Barnett and Salomon (2006) discuss the intricate trade-offs faced by large organizations when simultaneously pursuing corporate political activity and corporate investment for innovation or product development. They argue that while both initiatives demand substantial organizational resources, firms must navigate trade-offs to maximize their strategic outcomes effectively. Furthermore, these organizations often demonstrate accelerated growth trajectories and enhanced longevity in the business realm compared to their smaller counterparts, thereby reducing their reliance on governmental assistance and exhibiting a decreased need for extensive CPA (Bhagat, Bolton, 2008). Developing robust strategies in both market-oriented and non-market-oriented domains is essential for maintaining competitive advantages and fostering sustainable growth in the long term. However, the integra-

tion of these strategies presents formidable challenges, including resource constraints and conflicting organizational objectives. For instance, the allocation of resources for both market and non-market strategies may overlap, posing dilemmas for organizations striving to optimize resource utilization and achieve their strategic goals effectively (Bonardi, 2003). The simultaneous pursuit of CPA and corporate investment for innovation or product development necessitates substantial organizational resources and often entails complex trade-offs between these strategic imperatives. This trade-off dilemma is rooted in principles of economic rationality, wherein organizations endeavor to allocate resources efficiently to bolster their market power and enhance their competitive advantage (Taylor, 1997). Nevertheless, the integration of non-market strategies with organizational performance can be fraught with challenges, often giving rise to divergent viewpoints regarding the prioritization of market-oriented strategies vis-à-vis non-market ones. Nonetheless, businesses may view CPA as a non-market strategy offering long-term benefits for market enhancement, while innovation and product development initiatives present opportunities for rapid improvements in business performance. Consequently, firms may perceive CPA and innovation as alternative strategic avenues, each offering distinct pathways to enhancing organizational competitiveness and ensuring market viability (Ozer, Markóczy, 2010). Based on this, the following hypothesis is proposed:

Hypothesis H3: CPA has a negative relationship with corporate investment when the firm has a high investment level.

Methodology

Conditional Mean Methods - System Generalized Method of Moments

The study utilized several quantitative methods to test the hypothesis. In analyzing panel data, the System Generalized Method of Moments (System GMM) was employed as recommended by (Wooldridge, 2010; Roodman, 2006). This approach is useful for addressing issues related to bias in the dynamic panel and potential endogeneity that may arise from the correlation between the error term and independent variables. Recent literature confirms the applicability and effectiveness of System GMM in panel data analysis (Blundell, Bond, 2000), ensuring the robustness of the methodology used in this study.

The estimation comprised two parts. Initially, the dynamic model was formulated with the expressions specified below.

$$CorInv_{it} = \alpha + \beta_1 \, CorInv_{it-1} + \beta_2 \, CPA_{it} + \beta_3 Total\_Asset_{it} + \beta_4 Leverage_{it} + \beta_5 \, Free \; Cash \; Flow_{it} + \beta_6 \, Advertisement\_Intensity_{it} + \beta_7 \, Profitability_{it} + \mu_t + \varepsilon_{it} \qquad EQ(1)$$

$$E(\mu_t) = 0, \; E(\varepsilon_{it}) = 0, \; E(\mu_t \, \varepsilon_{it}) = 0 \; ; \; i = 1, \, ..., N \; ;$$
$$t = 2011. \, ,,, T \qquad\qquad EQ(2)$$

The study employs a panel data model where t and i represent time and firm, respectively. The dependent variable in the model is corporate investment (*CorInv*), while capital expenditure (*Capex*), R&D intensity, and asset growth (*Growth*) are used as proxy variables. The spending on corporate lobbying and PAC is denoted as CPA, and the time dummy parameters are represented by μt. The control variables in the model are *Total_Asset, Leverage, Free Cash Flow, Advertisement_Intensity*, and *Profitability*. The random error term is represented by ε_{it}. The System GMM approach is used to handle potential bias in the dynamic panel and to address endogeneity issues. The objective is to evaluate the impact of CPA on corporate investment while controlling for other relevant factors. EQ (2) establishes the conditions necessary for model estimation, ensuring that the error terms have a zero mean and are uncorrelated with the time dummy parameters. This validation step is crucial for confirming the validity of the System GMM estimator.

The study used a fixed-effect panel data model to control for potential endogeneity caused by unobserved firm-level factors that could be correlated with both the dependent variable (*CorInv*) and the independent variable (CPA). The fixed-effect model includes firm-specific indicators in addition to the predictor variables, and estimates how changes in CPA impact corporate investment. This allows for a comparison of a firm's investment against others in the sample at different time points. The model is expressed as follows:

$$\Delta CorInv_{it} = \alpha + \beta_1 \, CorInv_{it-1} + \beta_2 \Delta CPA_{it} + \beta_3 \Delta Total\_Asset_{it} + \beta_4 \Delta Leverage_{it} + \beta_5 \Delta Free \, Cash \, Flow_{it} + \beta_6 \Delta Advertisement\_Intensity_{it} + \beta_7 \Delta Profitability_{it} + \Delta \varepsilon_{it} \qquad EQ(3)$$

Here, *t* and *i* represent time and the firm, respectively. In this model, the variable $\Delta CorInv$ represents the difference between corporate investment for firm *i* at time *t* and the average value of corporate investment across all firms at that time. The fixed effects for each firm are represented by *αi*, which have a normal distribution with a mean of zero. Time dummy parameters are represented by μt, and changes to the control parameters are represented by $\Delta Total \, Asset, \Delta Leverage, \Delta Free \, Cash \, Flow, \Delta Advertisement \, Intensity$, and $\Delta Profitability$. By taking account of the differences of the variables, the model assesses changes in corporate investment relative to changes in *CPA, Total Asset, Leverage, Free Cash Flow, Advertisement Intensity,* and *Profitability* over time.

The fixed-effect model used in the study eliminated firm-related heterogeneity, but did not account for the data's dynamic structure. This could lead to the erroneous assumption that firm assets are not temporally associated. To address this, a dynamic panel data technique (Blundell, Bond, 1998) was used. The model includes an autoregressive dynamic component where the dependent variable (*CorInv*) at time *t* and firm *i* is influenced by the lagged dependent variable (*CorInvt-1*), which captures the stability of firm size over time. The model expression is given below:

$$CorInv_{it} = \alpha + \beta_1 \, CorInv_{it-1} + \beta_2 \, CPA_{it} + \beta_3 Total\_Asset_{it} + \beta_4 Leverage_{it} + \beta_5 \, Free \, Cash \, Flow_{it} + \beta_6 \, Advertisement\_Intensity_{it} + \beta_7 \, Profitability_{it} + \varepsilon_{it} \qquad EQ(4)$$

The adjustment parameter β_1 represents the steadiness in firm value, and αi denotes the fixed effects pertaining to the firm. The STATA 15 xtabond2 code (Roodman, 2006) was applied for this purpose, providing estimates of within-sample elements to ascertain the influence of changes in CPA on corresponding changes in corporate investment.

Panel Quantile Regression

The quantile regression (QR) technique (Koenker, Bassett, 1978) allows for the estimation of several models at conditional quantiles which represent equal-sized splits of the frequency distribution based on the dependent variable. This model is better suited for situations with outliers and non-normal errors, and provides a better characterization of the data, as it estimates the influence of the predictor variables over the complete distribution of the predicted variable as opposed to just the conditional mean. The QR method does not require strict assumptions about outliers, normality, or homoscedasticity. This approach is particularly advantageous for handling outliers and non-normal errors, offering robust estimations throughout the entire range of the dependent variable. Further research (Firpo et al., 2009; Chernozhukov, Hansen, 2005; Roodman, 2006; Wooldridge, 2010) has advanced the methodology, enhancing its applicability and performance in contemporary research settings.

The multiple linear regression framework expresses a dependent variable (*CorInv*) as a function of independent variables (CPA). The System GMM approach estimates the point effects of the independent variables by determining the average correlation shared by the dependent variable and its predictor variables. In this study, *CorInv* is the dependent variable, CPA is the independent variable, and the conditional mean is expressed as $E \, (CorInv|CPA) = CPA'$.

Consider that the observation samples are represented by ($CorInv_{it}$, CPA_{it}); i = 1, 2,…, N and t = 2016,…, T, where *t* and *i* denote the tth and ith time period and firm, respectively. $CorInv_{it}$ is the target corporate investment, while CPA_{it} denotes the (K×1) vector comprising exogenous parameters, in which political investment is also captured. The linear correlation between CPA_{it} and $CorInv_{it}$ is specified below:

$$CorInv_{it} = CPA'_{it} \, \beta + \varepsilon_{it} \qquad EQ(5)$$

Quantile regression is a statistical technique that estimates the relationship between variables at different points in the distribution of the dependent variable. Unlike conditional mean-based techniques, which provide a single estimate for the entire distribution of the dependent variable, quantile regression provides estimates for various quantiles, allowing us to analyze the relationship between the variables throughout the entire range of the dependent variable. Additionally,

quantile regression is robust to outliers and does not require assumptions regarding the distribution of errors.

The QR model's expression is specified based on the θth quantile corresponding to the dependent variable's (Y_{it}) conditional distribution, which is linear for X_{it}. This approach is particularly advantageous for handling outliers and non-normal errors, offering robust estimations throughout the entire range of the dependent variable.

$$Y_{it} = X'_{it}\beta_\theta + \varepsilon_{\theta it}$$
$$Q_\theta(Y_{it} \mid X_{it} = inf\{Y : F_{it}(Y_{it} \mid X_{it})\theta\} = X'_{it}\beta_\theta$$
$$Q_\theta(Y_{it} \mid \varepsilon_{\theta it}) = 0, \qquad\qquad EQ(6)$$

where $Q_\theta(Y_{it} \mid X_{it})$ denotes the θth conditional quantile corresponding to Y_{it} on the (K×1) vector comprising the independent variables X_{it}. β_θ represents the unknown parameter vector that needs to be determined for various values of θ from [0, 1] and $\varepsilon_{\theta it}$ denotes the error term. $F_{it}(. \mid X_{it})$ corresponds to the target variable distribution conditional on X_{it}. For any value of θ in the [0, 1] range, the complete distribution of Y conditional on X can be ascertained using the QR technique. The minimisation problem below corresponds to the estimation for β_θ.

$$\min \sum_{it:\varepsilon_{\theta it}>0} \theta\, X\, |\varepsilon_{\theta it}| + \sum_{it:\varepsilon_{\theta it}<0} (1-\theta)\, X\, |\varepsilon_{\theta it}| =$$

$$= \sum_{it\ Y_{it}-X'_{it}\beta>0} \theta\, X\, |Y_{it} - X'_{it}\beta| + \sum_{it\ Y_{it}-X'_{it}\beta<0} (1-\theta)\, X\, |Y_{it} - X'_{it}\beta| \quad (7)$$

Equation (7) describes the expression for the QR model, which can be used to estimate the θth QR estimator $((\beta\_\theta)\hat{})$ by minimizing the absolute weighted sum of the errors between the observed and fitted values, represented by Y_{it} and $X\_it\hat{}'\beta\_\theta$, respectively. Here, (1–θ) and θ denote the weights assigned to the observations with negative and positive residuals, respectively. The negative and positive residuals are represented by the first and second terms of Equation (7), respectively. A notable feature of the QR method is that the estimates of β_θ vary with the change in the value of θ, providing a way to determine the distribution of the effect of the exogenous variables on liquidity creation at different quantiles. The output of the QR method is the sample at the quantile. Since Equation (7) cannot be expressed in a simpler form, linear programming techniques are required for minimization (Hao, Naiman, 2007).

Data, Sample Selection, and Variables

Data. The research conducted in this study utilized data from a sample of 368 US firms included on the Fortune WMAC list between the years of 2016 and 2022, which coincided with the 2016 and 2022 US presidential elections, important political events during this time period. The WMAC list was selected to obtain data from a relatively uniform set of US companies, as these corporations actively invest significant capital in corporate political strategies (CRP, 2018). These companies were ideal for our analysis, as they are likely to consider each other political peers, a necessary condition for our empirical analysis. Additionally, the majority of Fortune WMAC companies and almost half of all mid-size US companies have programs to improve CPA, making them easily accessible for relevant data, which can be obtained from the CRP or the Federal Election Commission. The study utilized CPA data from the CRP's database (see above). The initial analysis included the evaluation of 384 top-performing companies on the 2022 WMAC list for the period from 2016 to 2022.

To avoid any issues related to sample selection, our study did not require a balanced panel, and the number of firms in the sample varied from year to year, with our estimation strategy using as many observations as were available. Additionally, to incorporate the dynamic dimension of our database, such as introducing the lagged value of the dependent variable, we observed firms for at least three consecutive years, excluding those that did not provide complete information. Ultimately, our unbalanced panel sample included 2,576 observations, with roughly 368 firms per year, covering the 2016 to 2022 period. Accounting data corresponding to the control variables and corporate investment was obtained from the Thomson Reuters Datastream, and after merging the data from Fortune's WMAC, Datastream, and CRP, the final sample consisted of 2,576 firm-years of data.

Corporate Political Activity. To measure CPA, we used a definition encompassing non-market activities, which involved one or more of the actions outlined by Hadani et al. (2017), such as (1) lobbying efforts, either in-house or through external hires, (2) PAC contributions or the presence of political connections between the organization and policymakers, such as politically connected personnel, directors, or stockholders, (3) any reported lobbying efforts or interactions with regulatory bodies through petitions, testimonies, or other means, and (4) political activity conducted by the trade association or umbrella body of which the organization in question is a part.

Corporate Investment. In our study, we defined corporate investment as any expenditure or asset purchase made with the goal of achieving higher income or value appreciation, which is not only for the present but also for future interests. The motivation behind such investments is the expectation that future returns will be greater than the initial investment. The focus of corporate investment is on acquiring assets that are expected to yield returns of their own. We used three measures to capture corporate investment: (1) Capital Expenditure (Capex), which is calculated as the capital expended, scaled by the sum of assets in the previous year; (2) Asset Growth, which indicates the rate of growth of total assets; and (3) R&D Intensity, which is

Table 1. **Industry Distribution of Firms in the Sample**	
Sector	**No of Firms**
Computer and Communication	35
Consumer Product	33
Contracted Services	35
Media and Entertainment	45
Natural Resources	34
Power	24
Precision	35
Shelter	41
Store and Distribution	53
Transportation	33
Total	368

Source: authors.

often seen as a determinant of corporate investment (Hill, Snell, 1988; Hoskisson et al., 1993) and as an indicator of efforts for innovation and invention. We measured R&D intensity by calculating R&D expenditure as a percentage of the total sales generated by the organization. These data points were obtained from the DataStream database. The following equations were used to calculate corporate investment:

$Capex = (Capital\ expenditure\ of\ firm) / (Total\ Assets)$ 　　　　EQ(8)

$Assets\ growth\ rate = (Total\ Assets_t - Total\ Assets_{t-1}) / Total\ Assets_{t-1}$ 　　　　EQ(9)

$R\&D\ Intensity = (Total\ R\&D\ Expendture) / (Total\ Sales)$ 　　　　EQ(10)

Control Variables. This study included multiple control variables at the industry, firm, and time levels to account for the small effects of CPA on the dependent variables. At the industry level, the 4-digit SIC code was used to control for differences in profitability across different markets within the industry. At the firm level, control variables included firm size, fixed asset size, liquidity, country of origin, and advertisement intensity. Firm size was measured by total assets, fixed assets were derived from the balance sheet, liquidity was measured by the current ratio, and profitability was measured by return on assets. Free cash flow was used to determine the amount of free cash available to the firm. All data points for control variables were obtained from the DataStream database.

Results and Discussion

Descriptive Statistical Analysis

In this section, the statistical summary of data used in the study is provided. The sample comprised 368 companies, generating 2,119 observations for each variable. The distribution of the firms across ten different industries is presented in Table 1, with transportation having the highest representation (26 firms) and power having the lowest. The sample's descriptive statistics and correlation matrix are presented in Tables 2 and 3, respectively. The study indicates that organizations incur debt to finance their operations and purchase assets, while the use of operating cash flow for such purposes remains limited. The variance in firm size was relatively small, considering revenue and asset context. Variable correlations were between 0.2655 and -0.0011, which can be categorized as low. The study uses the Variance Inflation Factor (VIF) to ascertain the presence of multicollinearity, and VIF values ranged between 1.06 and 6.29, which is an acceptable range given the maximum acceptable value of 10. The tolerance was between 0.1588 and 0.9977, while the mean VIF value stood at 2.69 for the studied parameters, confirming no multicollinearity issues.

Table 2. **Descriptive Statistics Summary**						
Variable	Measure Used	Observation	Mean	Std Dev	Min	Max
Capex	Ratio of capital expenditure to total asset	2576	0.0947	0.1835	0.3552	1.3243
Asset Growth	Ratio of different change in Assets over a given period	2576	0.1949	0.4889	0.2818	2.1235
ln CPA	Logarithm total CPA of company i in year t	2576	8.3706	1.8334	0.2451	12.4798
Profitability	Return of Asset	2576	8.3895	1.8176	4.2271	12.4521
ln Total Asset	Logarithm of the total assets of company i in year t	2576	8.7292	1.8956	8.2271	13.5217
R&D Intensity	Ratio of R&D expenditures to total assets of company i in year t	2576	0.0486	0.1014	0.0245	1.5148
Leverage	Liabilities divided by total assets to measure i in year t	2576	1.1966	0.6941	0.1133	6.8989
Free Cash Flow	Logarithm of free cash flow of company i in year t	2576	0.0360	0.1929	-5.7142	0.89491
Advertising Intensity	Ratio of advertising expenditures to total assets of company i in year t	2576	0.1486	0.0914	0.2245	0.51428

Notes: All statistics are based on original data values.
Source: authors.

Table 3. **Correlation Matrix**

Variable	Capex	Asset Growth	ln CPA	Profitability	ln Total Asset	R&D Intensity	Free Cash Flow	Advertising Intensity	Leverage
Capex	1								
Asset Growth	0.0775	1							
ln CPA	0.1623	0.0333	1						
Profitability	0.1198	0.0138	0.0463	1					
ln Total Asset	-0.0109	-0.0021	-0.0025	-0.0201	1				
R&D Intensity	0.1510	0.0865	0.0602	0.2874	-0.073	1			
Free Cash Flow	0.0118	-0.0011	0.0011	0.0484	-0.0013	0.0998	1		
Advertising Intensity	0.0892	0.0194	0.0082	0.0375	-0.0038	0.2665	-0.0033	1	
Leverage	0.0754	0.0462	-0.0239	0.0355	-0.0235	0.2189	-0.0375	-0.0169	1

Source: authors.

Conditional Mean Method - System GMM Results

To estimate the CPA-Corporate Investment framework, we employed dynamic panel data and the two-step Generalized Method of Moments (GMM) estimation technique. This approach offers the advantage of eliminating unobservable firm-specific effects that remain constant over time. By taking the first difference for every parameter, such effects are effectively removed. Additionally, utilizing this technique helps manage correlations between the regressors and the error terms efficiently. Moreover, it reduces the likelihood of endogeneity by incorporating lagged values of difference equations and level variations that constitute the first differences.

In this study, we utilized the estimated values of Asset Growth, Capex, and R&D intensity to model corporate investment, while CPA was utilized to assess the impact of dynamic CPA on the correlations and heterogeneity of corporate investment. To ensure the robustness of the model, misspecification testing was conducted through AR(1) and AR(2) second-order serial correlation tests, as well as the Hansen test to examine constraints. The results indicated high p-values, signifying no residual correlation and validating the instrument and estimate consistency of the System GMM. Moreover, the study further validated the applicability of the System GMM model specification using authentication. The lagged dependents were found to have positive coefficients and statistical significance, suggesting that past financial performance significantly influences the present.

The evidence presented in Table 4 supports a positive relationship between CPA and corporate invest-

Table 4. **The effect of CPA on Corporate Investment**

Variable	System GMM		
	Asset Growth	**R&D Intensity**	**Capex**
Asset Growth$_{t-1}$	0.197*** (-0.03)	-	-
R&D Intensity$_{t-1}$		0.122*** (-0.00529)	-
CAPEX$_{t-1}$	-	-	0.0712* (-0.0381)
ln CPA	0.1106*** (-0.0209)	0.00227* (-0.00126)	0.0917*** (-0.0234)
ln Total Assets	-0.00685 (-0.0402)	-0.00279*** (-0.00103)	-0.0630*** (-0.0221)
Leverage	0.285*** (-0.0168)	0.00743 (-0.00895)	-0.000422 (-0.000465)
Advertising Intensity	1.774*** (-0.521)	-6.13E-05 (-6.05E-05)	-0.0439 (-0.1340)
Free Cash Flow	1.799* (-1.014)	-7.44E-05 (-5.20E-05)	0.0204 (-0.0810)
Profitability	1.2300 (-1.909)	0.000689 (-0.0015)	0.00215*** (-0.000762)
Constant	-0.0958 (-0.309)	0.0123* (-0.00638)	-0.129*** (-0.0479)
Observations	2576	2576	2576
Number of groups	368	368	368
Number of Instruments	23	23	23
R-squared	-	-	-
AR(1)	-1.39(0.029)	-1.07(0.028)	-2.35(0.019)
AR(2)	-2.45(0.707)	-1.05(0.293)	1.61(0.107)
Hansen Test	19.75(0.182)	8.72(0.892)	24.32(0.090)
Difference in Hansen Test	3.82(0.575)	3.492(0.900)	15.01(0.710)

Note: Statistical significance is based on firm-level clustered standard errors. ***, ** and * denote statistical significance at 1%, 5% and 10% respectively. The standard errors are reported in parentheses.
Source: authors.

Table 5. Results of the Quantile Dynamic Panel Model with Capex as the Corporate Investment Measure (*Capex*)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Variables	$\tau = 0.10$	$\tau = 0.20$	$\tau = 0.30$	$\tau = 0.40$	$\tau = 0.50$	$\tau = 0.60$	$\tau = 0.70$	$\tau = 0.80$	$\tau = 0.90$
Capex$_{t-1}$	0.381*** (0.00428)	0.388*** (0.00463)	0.465*** (0.0131)	0.427*** (0.000845)	0.403*** (0.00566)	0.373*** (0.00849)	0.379*** (0.00275)	0.345*** (0.00333)	0.321*** (0.0157)
ln CPA	0.00293*** (9.77e-05)	0.000608*** (0.000120)	0.000641*** (0.000124)	-0.00194*** (1.69e-05)	-0.00191*** (0.000118)	-0.00448*** (0.000132)	-0.00359*** (6.74e-05)	-0.00493*** (8.34e-05)	-0.00552*** (0.000299)
ln total Assets	6.14e-09 (5.75e-09)	2.35e-08*** (1.91e-09)	3.55e-08*** (2.48e-09)	5.16e-08*** (3.04e-10)	3.52e-08*** (1.90e-09)	6.86e-08*** (2.39e-09)	4.24e-08*** (9.87e-10)	5.21e-08*** (2.19e-09)	2.07e-08*** (3.27e-09)
Leverage	-2.05e-05 (5.89e-05)	8.17e-05 (9.17e-05)	-0.000374*** (7.12e-05)	-0.000220*** (1.28e-05)	-0.000222*** (9.72e-05)	-3.25e-05 (9.12e-05)	-0.000163*** (1.75e-05)	-0.000221*** (2.19e-05)	-0.000212*** (6.22e-05)
Advertising Intensity	-0.109*** (0.00290)	-0.0595*** (0.00551)	-0.0317*** (0.00304)	-0.0267*** (0.000450)	-0.0165*** (0.00183)	0.00268 (0.00238)	0.0216*** (0.00155)	0.0488*** (0.000782)	0.0342*** (0.00670)
Free Cash Flow	0.0491*** (0.00216)	0.0307*** (0.00255)	0.0229*** (0.00608)	0.0533*** (0.000271)	0.0595*** (0.00343)	0.0564*** (0.00282)	0.0560*** (0.000830)	0.0528*** (0.00189)	0.0261*** (0.00317)
Profitability	0.288*** (0.00368)	0.317*** (0.00193)	0.292*** (0.00734)	0.313*** (0.000339)	0.322*** (0.00384)	0.354*** (0.00418)	0.359*** (0.00195)	0.385*** (0.00167)	0.400*** (0.00833)
Observations	2576	2576	2576	2576	2576	2576	2576	2576	2576
Number of groups	368	368	368	368	368	368	368	368	368

Note: *, **, *** means significant at 10%, 5% and 1% respectively. CPA = corporate political activity.
Source: authors..

ment. Models 1, 2, and 3 demonstrate that all three variables (Asset Growth, R&D Intensity, and Capex) have significantly positive coefficients with corporate investment (e.g., β = 0.11065, p-value < 0.001 for Asset Growth; β = 0.00227, p-value < 0.01 for R&D Intensity; and β = 0.0917, p-value < 0.005 for Capex). These findings indicate that as CPA increases, its impact on corporate investment also rises, supporting Hypothesis 1. The positive correlation between CPA and corporate investment aligns with previous studies (Czarnitzki, Toole, 2007; Hyytinen, Toivanen, 2005), suggesting that government initiatives to alleviate market uncertainty for new products through project subsidies and capital funding can facilitate businesses in securing investments and addressing financial challenges.

It appears from the study's findings that well-established, large firms with limited growth avenues and low risk tend to strategically engage in political activities and exhibit higher levels of R&D spending, asset growth, and capital expenditure. These firms also tend to outperform politically disconnected firms in terms of corporate investment. These findings are consistent with prior research on the relationship between corporate political activity and business performance. Additionally, the study suggests that higher salaries paid to political delegates may be associated with better business performance.

Table 6. Results of the Quantile Dynamic Panel Model with Asset Growth as the Corporate Investment Measure (*Asset Growth*)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Variables	$\tau = 0.10$	$\tau = 0.20$	$\tau = 0.30$	$\tau = 0.40$	$\tau = 0.50$	$\tau = 0.60$	$\tau = 0.70$	$\tau = 0.80$	$\tau = 0.90$
Asset Growth$_{t-1}$	0.0585*** (0.000377)	0.0497*** (0.000227)	0.0439*** (0.000892)	0.0369*** (0.000233)	0.0348*** (0.00236)	0.0649*** (0.000104)	0.0383*** (0.000531)	0.0330*** (0.000653)	0.0677*** (0.00310)
ln CPA	0.00391*** (0.000190)	0.00198*** (0.000234)	0.000566** (0.000236)	0.00120*** (0.000148)	-0.00183*** (0.000432)	-0.00282*** (0.000204)	-0.00493*** (9.31e-05)	-0.00626*** (0.000146)	-0.0151*** (0.00101)
ln total Assets	-6.04e-09 (4.54e-09)	-1.47e-07*** (1.09e-08)	-2.26e-07*** (5.82e-09)	-3.94e-07*** (8.01e-09)	-3.30e-07*** (7.71e-09)	-2.52e-07*** (3.64e-09)	-2.81e-07*** (3.83e-09)	-3.77e-07*** (2.60e-09)	-2.78e-07*** (7.50e-09)
Leverage	0.0878*** (0.000190)	0.136*** (0.000106)	0.158*** (0.000370)	0.196*** (8.55e-05)	0.238*** (0.000618)	0.237*** (6.36e-05)	0.268*** (0.000226)	0.317*** (0.000242)	0.318*** (0.000524)
Advertising Intensity	-0.0234** (0.0110)	-0.0155*** (0.00511)	-0.0220*** (0.00436)	-0.0236*** (0.00160)	0.00984 (0.0142)	-0.0267*** (0.00263)	-0.0387*** (0.00208)	0.0529*** (0.00451)	0.163*** (0.0185)
Free Cash Flow	0.0207*** (0.00379)	0.0902*** (0.00988)	0.0468*** (0.00792)	0.0699*** (0.00382)	0.0588* (0.0340)	0.128*** (0.00327)	0.211*** (0.00259)	0.318*** (0.00944)	0.515*** (0.0416)
Profitability	1.017*** (0.00367)	1.071*** (0.00295)	1.118*** (0.0113)	1.200*** (0.00297)	1.244*** (0.00663)	1.169*** (0.00264)	1.155*** (0.00256)	1.068*** (0.00420)	1.017*** (0.0136)
Observations	2576	2576	2576	2576	2576	2576	2576	2576	2576
Number of groups	368	368	368	368	368	368	368	368	368

Note: *, **, *** means significant at 10%, 5% and 1% respectively. CPA = corporate political activity.
Source: authors..

Table 7. **Results of the Quantile Dynamic Panel Model with R&D Intensity as the Corporate Investment Measure (*R&D intensity*)**									
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Variables	τ = 0.10	τ = 0.20	τ = 0.30	τ = 0.40	τ = 0.50	τ = 0.60	τ = 0.70	τ = 0.80	τ = 0.90
R&D Intensity $_{t-1}$	0.610*** (0.0212)	0.651*** (0.000440)	0.776*** (0.000504)	0.823*** (0.00168)	0.816*** (0.000261)	0.837*** (0.00487)	0.846*** (0.00248)	0.839*** (0.0136)	0.816*** (0.00210)
ln CPA	38.71** (17.70)	36.05*** (0.347)	22.98*** (0.279)	24.96*** (0.983)	-41.06*** (0.295)	-32.06*** (1.196)	-27.39*** (2.277)	-27.86*** (7.312)	-30.91*** (1.140)
ln total Assets	0.0148*** (0.00167)	0.0205*** (2.74e-05)	0.0190*** (2.79e-05)	0.0187*** (0.000128)	0.0202*** (1.10e-05)	0.0228*** (0.000437)	0.0260*** (0.000202)	0.0313*** (0.000781)	0.0391*** (0.000162)
Leverage	-4.730 (5.234)	-0.386*** (0.00833)	-1.247*** (0.101)	0.464 (0.466)	0.275*** (0.0181)	-1.459 (1.698)	-0.487 (0.462)	0.367 (2.024)	-0.336 (0.751)
Advertising Intensity	-160.9 (328.2)	13.72*** (2.994)	43.64*** (2.244)	-37.12*** (6.591)	-41.68*** (0.687)	-53.09 (61.95)	-96.76** (43.96)	-70.34** (34.28)	-28.11 (43.53)
Free Cash Flow	-568.3 (578.8)	84.83*** (3.547)	125.3*** (3.540)	138.7*** (22.10)	121.1*** (2.066)	-73.84 (138.9)	123.6* (71.38)	-37.44 (124.7)	-16.75 (38.05)
Profitability	-153.4 (348.2)	220.5*** (1.320)	167.9*** (4.124)	176.0*** (5.060)	156.3*** (1.148)	340.3*** (131.0)	238.2*** (59.30)	238.2*** (66.42)	96.74*** (22.97)
Observations	2576	2576	2576	2576	2576	2576	2576	2576	2576
Number of groups	368	368	368	368	368	368	368	368	368

Note: *, **, *** means significant at 10%, 5% and 1% respectively. CPA = corporate political activity.
Source: authors..

Panel Quantile Regression

The results of the study show that the effects of CPA on corporate investment vary across different quantiles of the independent and dependent variables. Specifically, lower quantiles of CPA (from 0.10 to 0.40) have a positive influence on corporate investment, while higher quantiles (from 0.50 to 0.90) lead to adverse effects. This suggests that positive changes in CPA negatively affect corporate investment. The details of the quantile estimate results can be found in Tables 5, 6, and 7.

Lower Quantiles (0.10 - 0.40). According to the results presented in Tables 5, 6, and 7, the relationship between CPA and corporate investment varies depending on the quantiles of the variables. In particular, low-investment firms in the 10th and 40th quantiles benefit from the positive influence of CPA on investment, while high-investment firms in the 50th to 90th quantiles experience negative effects of CPA on investment. This finding suggests that firms with low investment levels, especially those in the lower quantiles, should emphasize developing their connections with the government and engaging in CPA. Doing so would enable them to receive support and resources from the government, reduce market-based risks, access preferential debt-based finance and tax benefits, and enhance their political capital. These benefits would make them more resilient to market pressures and better positioned to compete. The results are consistent with previous studies that highlight the value of CPA in improving business performance (Houston et al., 2014; Tee, 2018) and reducing uncertainty (Mitnick, 1993). Moreover, engaging in CPA may allow firms to influence policy and regulations in their favor and gain access to large government projects (Gomez et al., 2017).

Higher Quantiles (0.50 - 0.90). The results from Tables 5, 6, and 7 suggest that, on average investment levels, corporate political activity (CPA) has a negative impact on corporate investment in higher quantiles (50th and 90th). This indicates that firms in these quantiles should not rely on government resources to enhance their corporate investments. After a certain threshold of investment, organizations should not focus on building excessive dependence on the government through CPA; instead, they should concentrate on increasing sales on their markets. Higher sales are essential to mobilize corporate investments, which is more effective than CPA investment. Sales increase cash flow, which enables market expansion, improved technology, increased capital, and better promotion and development. Therefore, firms with higher corporate investment levels should concentrate on strengthening their market presence, increasing sales, and working toward a sustainable competitive advantage to facilitate better corporate investment. Hence, Hypothesis 3 is supported.

Conclusion

The study collected data on corporate investment and CPA from various databases, including DataStream, CRP, and Fortune WMAC, from 2016 to 2022 to analyze the relationship between CPA and corporate investment. The study used a detailed set of variables to model the socioeconomic and political characteristics of US institutions. The analysis showed that firms engaged in CPA have higher levels of corporate investment compared to those that do not use CPA. This positive effect is statistically significant for firms in the middle quantile who are likely to receive government support through CPA. The study's findings suggest a

correlation between CPA-facilitated corporate investments, commercial benefits, and government support from a socioeconomic policy perspective.

According to this research, the relationship between CPA and corporate investment is affected by the investment level of the firm. The study supports the resource dependence theory and the political patronage theory, which suggests that CPA and corporate investment are complementary. The results also indicate that politically strategic firms have low levels of corporate investment at higher quantiles, whereas firms at lower quantiles have higher levels of corporate investment. This leads to an inverse V-shaped association between CPA and corporate investment. The study found that larger firms are less influenced by CPA, as they have strong economic and technical power, and do not need to rely on government support to increase their investment. While prior research suggests that politically connected firms have higher levels of investment, the evidence is mixed for low or high capital-intensive firms in this study.

In conclusion, this study illustrates the dynamic changes in CPA levels and their impact on corporate investment in the US, where political patronage is a significant factor in the system (Danaei et al., 2013). Based on our analysis of 2,576 records, our findings suggest a strong relationship between CPA and corporate investment, despite the associated risks. This study suggests that the level of corporate investment varies across different CPA scales, with aggressive firms projected to have better investment outcomes compared to their moderate counterparts. Thus, CPA efforts seem to help aggressive organizations engage in better corporate investment. It is important to understand the strong relationship between CPA and corporate investment since numerous studies have used meta-analysis to identify factors influencing corporate investment. Comparing the organizational benefits of CPA with other factors,

such as government support and trade protection, we find that CPA provides a meaningful boost to performance, with benefits equaling or exceeding other factors. Based on cost comparisons, CPA appears to be the most advantageous strategy for maintaining a sustainable advantage and staying ahead of competitors. In conclusion, it is crucial for firms to leverage CPA to their advantage and invest in it as much as possible to ensure their long-term competitiveness.

This study found that larger firms with significant market share tend to be more politically active, while small and medium-sized enterprises (SMEs) can benefit more from CPA since they have lower levels of corporate investment. Business managers believe they can offset the individual costs of political efforts by earning a share of public policy benefits. Political strategy can also help firms avoid downsizing. When facing threats from competitors, political engagement may be one of the few strategic options available, particularly for industries with high exit costs. Firms facing national and international competitive pressure should employ an organization-level strategy that complements their public policy strategy to better understand the factors that motivate businesses to seek government protection.

This study examined the relationship between CPA and corporate investment, but has some limitations. Firstly, the sample only included listed US companies due to data availability, which may not represent unlisted companies. Secondly, the sample size of corporations engaged in political donations was limited, although the seven-year period compensates for this. Thirdly, the chosen sample may not be comprehensive, which could affect the study's findings. Future research should explore different types of political donations, test the legitimacy theory with other legitimacy strategies, and investigate ethics' role in the contexts of CPA and corporate investment.

References

Alok S., Ayyagari M. (2020) Politics, state ownership, and corporate investments. *The Review of Financial Studies*, 33(7), 3031–3087. https://doi.org/10.1093/rfs/hhz102

An H., Chen Y., Luo D., Zhang T. (2016) Political uncertainty and corporate investment: Evidence from China. *Journal of Corporate Finance*, 36, 174–189. https://doi.org/10.1016/j.jcorpfin.2015.11.003

Anastasiadis S., Moon J., Humphreys M. (2018) Lobbying and the responsible firm: Agenda-setting for a freshly conceptualized field. *Business Ethics*, 27(3), 207–221. https://doi.org/10.1111/beer.12180(2)

Ashyrov G., Lukason O. (2022) Political Connectedness and Financial Performance of SMEs. *Journal of Risk and Financial Management*, 15(12), 600. https://doi.org/10.3390/jrfm15120600

Barnett M.L., Salomon R.M. (2006) Beyond dichotomy: The curvilinear relationship between social responsibility and financial performance. *Strategic Management Journal*, 27(11), 1101–1122. https://doi.org/10.1002/smj.557

Bertrand J., Perrin C. (2024) *Does Corporate Political Activity (Really) Reduce Discouragement? The Paradox of Women-Led Firms* (SSRN paper 4743152). https://dx.doi.org/10.2139/ssrn.4743152

Beugelsdijk S., Cornet M. (2002) A Far Friend is Worth More than a Good Neighbour': Proximity and Innovation in a Small Country. *Journal of Management & Governance*, 6, 169–188. https://doi.org/10.1023/A:1015775321949

Bhagat S., Bolton B. (2008) Firm size and the effectiveness of the market for corporate control. *Journal of Corporate Finance*, 14, 257–273. https://doi.org/10.1016/j.jcorpfin.2008.03.006

Bliss M.A., Gul F.A. (2012) Political connection and cost of debt: Some Malaysian evidence. *Journal of Banking & Finance*, 36(5), 1520–1527. https://doi.org/10.1016/j.jbankfin.2011.12.011

Blundell R., Bond S. (1998) Initial conditions and moment restrictions in dynamic panel data models. *Journal of Econometrics*, 87(1), 115–143. https://doi.org/10.1016/S0304-4076(98)00009-8

Blundell R., Bond S. (2000) GMM estimation with persistent panel data: An application to production functions. *Econometric Reviews,* 19(3), 321–340. https://doi.org/10.1080/07474930008800475

Bonardi J.P. (2003) Global and political strategies in deregulated industries: The asymmetric behaviors of former monopolies. *Strategic Management Journal,* 25(2), 101–120. https://doi.org/10.1002/smj.367

Brown L.W., Liou R.S., Hasija D. (2023) Emerging market multinational corporations' cross-border mergers and acquisitions and political distance: Does corporate political activity matter?. *Thunderbird International Business Review*, 65(5), 533–546. https://doi.org/10.1002/tie.22355

Byrd R.C. (1991) *The Senate, 1789–1989* (vol. II), Washington, D.C.: United States Senate.

Chernozhukov V., Hansen C. (2005) An IV model of quantile treatment effects. *Econometrica,* 73(1), 245–261. https://www.jstor.org/stable/3598944

Child J. (1972) Organizational structure, environment and performance: The role of strategic choice. *Sociology*, 6(1), 1–22. http://dx.doi.org/10.1177/003803857200600101

Cooper M.J., Gulen H., Ovtchinnikov A.V. (2010) Corporate political contributions and stock returns. *The Journal of Finance*, 65(2), 687–724. https://www.jstor.org/stable/25656307

Czarnitzki D., Toole A.A. (2007) Business R&D and the interplay of R&D subsidies and product market uncertainty. *Review of Industrial Organization*, 31(3), 169–181. https://doi.org/10.1007/s11151-007-9152-x

Danaei A., Jabbari M., Omidifar L. (2013) Strategic planning and performance measurement using Fuzzy DEMATEL: A case study of Iran Kaolin and Barite company. *Decision Science Letters*, 2(4), 231–240. https://doi.org/10.5267/J.DSL.2013.05.003

Denisov D. (2010) *Business lobbying and government relations in Russia: The need for new principles* (Reuters Institute Fellowship Paper), Oxford: University of Oxford.

Faccio M. (2010) Differences between politically connected and nonconnected firms: A cross-country analysis. *Financial Management*, 39(3), 905–928. https://doi.org/10.1111/j.1755-053X.2010.01099.x

Fan J.P., Wong T.J., Zhang T. (2007) Politically connected CEOs, corporate governance, and Post-IPO performance of China's newly partially privatized firms. *Journal of Financial Economics*, 84(2), 330–357. https://doi.org/10.1016/j.jfineco.2006.03.008

Firpo S., Fortin N., Lemieux T. (2009) Unconditional quantile regressions. *Econometrica,* 77(3), 953–973. https://www.jstor.org/stable/40263848

Fung S.Y., Gul F.A., Radhakrishnan S. (2015) Corporate political connections and the 2008 Malaysian election. *Accounting, Organizations and Society*, 43, 67–86. https://doi.org/10.1016/j.aos.2015.04.001

Funk R.J., Hirschman D. (2017) Beyond nonmarket strategy: Market actions as corporate political activity. *Academy of Management Review,* 42(1), 32–52. https://www.jstor.org/stable/24906274

Galvao A.F. (2011) Quantile regression for dynamic panel data with fixed effects. *Journal of Econometrics*, 164(1), 142–157. https://doi.org/10.1016/j.jeconom.2011.02.016

Getz K.A. (1997) Research in corporate political action: Integration and assessment. *Business & Society*, 36(1), 32–72. https://doi.org/10.1177/000765039703600103

Goldman E., Rocholl J., So J. (2009) Do politically connected boards affect firm value?. *The Review of Financial Studies*, 22(6), 2331–2360. https://www.jstor.org/stable/30225718

Goldstraw-White J., Martin G. (2016) Tackling bribery and corruption in the Middle East: Perspectives from the front line. *Journal of Financial Crime*, 23(4), 843–854 https://doi.org/10.1108/JFC-08-2015-0040

Gomez E.T., Padmanabhan T., Kamaruddin N., Bhalla S., Fisal F. (2017) *Minister of finance incorporated: Ownership and control of corporate Malaysia*, Heidelberg, Dordrecht, London, New York: Springer.

Guedhami O., Pittman J.A., Saffar W. (2014) Auditor choice in politically connected firms. *Journal of Accounting Research*, 52(1), 107–162. https://doi.org/10.1111/1475-679X.12032

Gulen H., Ion M. (2016) Policy uncertainty and corporate investment. *The Review of Financial Studies*, 29(3), 523–564. https://doi.org/10.1093/rfs/hhv050

Hadani M., Bonardi J.P., Dahan N.M. (2017) Corporate political activity, public policy uncertainty, and firm outcomes: A meta-analysis. *Strategic Organization*, 15(3), 338–366. https://doi.org/10.1177/1476127016651001

Hart D.M. (2001) Why do some firms give? Why do some give a lot?: High-tech PACs, 1977–1996. *Journal of Politics*, 63(4), 1230–1249. https://doi.org/10.1111/0022-3816.00108

Hill C.W., Snell S.A. (1988) External control, corporate strategy, and firm performance in research-intensive industries. *Strategic Management Journal*, 9(6), 577–590. https://doi.org/10.1002/smj.4250090605

Hill M.D., Kelly G.W., Lockhart G.B., Van Ness R.A. (2013) Determinants and Effects of Corporate Lobbying. *Financial Management,* 42(4), 931–957. http://www.jstor.org/stable/43280520

Hillman A.J., Keim G.D. (2001) Shareholder value, stakeholder management, and social issues: What's the bottom line? *Strategic Management Journal*, 22(2), 125–139. https://doi.org/10.1002/1097-0266(200101)22:2<125::AID-SMJ150>3.0.CO;2-H

Hillman B. (2005) Monastic politics and the local state in China: Authority and autonomy in an ethnically Tibetan prefecture. *The China Journal*, (54), 29–51. https://doi.org/10.2307/20066065

Hoskisson R.E., Hitt M.A., Johnson R.A., Moesel D.D. (1993) Construct validity of an objective (entropy) categorical measure of diversification strategy. *Strategic Management Journal*, 14(3), 215–235. https://doi.org/10.1002/smj.4250140305

Houston J.F., Jiang L., Lin C., Ma Y. (2014) Political connections and the cost of bank loans. *Journal of Accounting Research*, 52(1), 193–243. https://doi.org/10.1111/1475-679X.12038

Hyytinen A., Toivanen O. (2005) Do financial constraints hold back innovation and growth?: Evidence on the role of public policy. *Research Policy*, 34(9), 1385–1403. https://doi.org/10.1016/j.respol.2005.06.004

Jackowicz K., Kozłowski Ł., Mielcarz P. (2014) Political connections and operational performance of non-financial firms: New evidence from Poland. *Emerging Markets Review*, 20, 109–135. https://doi.org/10.1016/j.ememar.2014.06.005

Khaw K.L.H., Zainudin R., Rashid R.M. (2019) Cost of debt financing: Does political connection matter? *Emerging Markets Review*, 41(C). https://doi.org/10.1016/j.ememar.2019.100632

Koenker R., Bassett G. (1982) Robust tests for heteroscedasticity based on regression quantiles. *Econometrica*, 43–61. https://doi.org/10.2307/1912528

Lawton T., McGuire S., Rajwani T. (2013) Corporate political activity: A literature review and research agenda. *International Journal of Management Reviews*, 15(1), 86–105. https://doi.org/10.1111/j.1468-2370.2012.00337.x

Lee J.Y., Jiménez A., Choi S., Choi Y.H. (2022) Ideological polarization and corporate lobbying activity: The contingent impact of corruption distance. *Journal of Business Research,* 141, 448–461. https://doi.org/10.1016/j.jbusres.2021.11.047

Lin J., Si S.X. (2010) Can guanxi be a problem? Contexts, ties, and some unfavorable consequences of social capital in China. *Asia Pacific Journal of Management*, 27(3), 561–581. https://doi.org/10.1007/s10490-010-9198-4

Lin W.L. (2019) Do firm's organisational slacks influence the relationship between corporate lobbying and corporate financial performance? More is not always better. *International Journal of Financial Studies*, 7(1), 2. https://doi.org/10.3390/ijfs7010002

Lin W.L. (2020) Giving too much and paying too little? The effect of corporate social responsibility on corporate lobbying efficacy: Evidence of tax aggressiveness. *Corporate Social Responsibility and Environmental Management*, 28(2), 908–924. https://doi.org/10.1002/csr.2098

Lin W.L., Sambasivan M., Ho J.A., Law S.H. (2019) Corporate Political Activity and Financial Performance: A Corporate Social Responsibility Perspective. In: Proceedings of the *International Symposia in Economic Theory and Econometrics 'Asia-Pacific Contemporary Finance and Development'* (vol. 26), pp. 235–264. https://doi.org/10.1108/S1571-038620190000026012

Liou R.-S., Brown L.W., Hasija D. (2021) Political animosity in cross-border acquisitions: EMNCs' market and nonmarket strategy in a developed market. *Multinational Business Review,* 29(4), 451–475. https://doi.org/10.1108/MBR-02-2020-0034

Liu H., Yang J.Y., Augustine D. (2018) Political ties and firm performance: The effects of proself and prosocial engagement and institutional development. *Global Strategy Journal*, 8(3), 471–502. https://doi.org/10.1002/gsj.1194

Lux S., Crook T.R., Woehr D.J. (2011) Mixing business with politics: A meta-analysis of the antecedents and outcomes of corporate political activity. *Journal of Management*, 37(1), 223–247. https://doi.org/10.1177/0149206310392233

Ma Y., Xue L. (2024) Organizational legitimacy and firm nonmarket strategies as catalysts of alliance green management. *Journal of Cleaner Production*, 447, 141315. https://doi.org/10.1016/j.jclepro.2024.141315

Massaro M. (2019) Is business lobbying in the European Union context-dependent? Evidence from the policy field of radio spectrum. *Telecommunications Policy,* 43(10), 101827. https://doi.org/10.1016/j.telpol.2019.101827

Mitnick B.M. (1993) *Corporate political agency: The construction of competition in public affairs,* Thousand Oaks, CA: Sage Publications.

Ozer M., Markóczy L. (2010) Complementary or alternative? The effects of corporate political strategy on innovation. *Journal of Strategy and Management,* 3(3), 252–272 https://doi.org/10.1108/17554251011064846

Piotroski J.D., Wong T.J., Zhang T. (2015) Political incentives to suppress negative information: Evidence from Chinese listed firms. *Journal of Accounting Research*, 53(2), 405–459. https://doi.org/10.1111/1475-679X.12071

Ramesh V.K. (2024) Does economic and policy uncertainty impact corporate policies? Evidence from India. *Indian Growth and Development Review*, 17(1), 43–62. https://doi.org/10.1108/IGDR-09-2022-0107

Romann E. (2020) *Nonmarket Strategy in Japan: How Foreign Firms Lobby "Inside the Castle"* (1st ed.), New York: Macmillan.

Roodman D. (2006) How to do xtabond2: An introduction to difference and system GMM in Stata. *The Stata Journal,* 9(1), 86–136.

Rudy B.C., Cavich J. (2020) Nonmarket signals: Investment in corporate political activity and the performance of initial public offerings. *Business & Society*, 59(3), 419–438. https://doi.org/10.1177/0007650317717263

Shi W., Hoskisson R.E., Zhang Y. (2020) Corporate political activities and firm performance: Evidence from China. *Management and Organization Review,* 16(1), 107–137. https://doi.org/10.1017/mor.2018.38

Shleifer A., Vishny R.W. (1994) Politicians and firms. *The Quarterly Journal of Economics*, 109(4), 995–1025. https://doi.org/10.2307/2118354

Slater S., Lawrence M., Wood B., Serodio P., Baker P. (2024) Corporate interest groups and their implications for global food governance: mapping and analysing the global corporate influence network of the transnational ultra-processed food industry. *Globalization and Health,* 20(16), 1–15. https://doi.org/10.1186/s12992-024-01020-4

Sutton T., Devine R.A., Lamont B.T., Holmes R.M. (2021) Resource dependence, uncertainty, and the allocation of corporate political activity across multiple jurisdictions. *Academy of Management Journal*, 64(1), 38–62. https://doi.org/10.5465/amj.2017.1258

Taylor C. (1997) The politics of recognition. In: *New Contexts of Canadian Criticism* (ed. A. Gutman), Princeton, NJ: Princeton University Press, pp. 25–73.

Tee C. (2018) The Gülen Movement in London and the politics of public engagement: Producing 'good Islam' before and after 15 July. *Politics, Religion & Ideology*, 19(1), 109–122. https://doi.org/10.1080/21567689.2018.1453269

Tyler B., Lahneman B., Cerrato D., Cruz A.D., Beukel K., Spielmann N., Minciullo M. (2023) Environmental practice adoption in SMEs: The effects of firm proactive orientation and regulatory pressure, *Journal of Small Business Management,* 2218435. https://doi.org/10.1080/00472778.2023.2218435

Wang D., Sutherland D., Ning L., Wang Y., Pan X. (2018) Exploring the influence of political connections and managerial overconfidence on R&D intensity in China's large-scale private sector firms. *Technovation*, 69, 40–53. https://doi.org/10.1016/j.technovation.2017.10.007

Wooldridge J.M. (2010) *Econometric analysis of cross section and panel data*, Cambridge, MA: MIT Press.

Wu J., Li S., Li Z. (2013) The contingent value of CEO political connections: A study on IPO performance in China. *Asia Pacific Journal of Management*, 30(4), 1087–1114. https://doi.org/10.1007/s10490-012-9300-1

Xu X., Yan Y. (2020) Effect of political connection on corporate environmental investment: Evidence from Chinese private firms. *Applied Economics Letters*, 27(18), 1515–1521. https://doi.org/10.1080/13504851.2019.1693692

ICT Profiles of Russian Companies at the Industry Level: Resource Management Strategies

Mariya Molodchik

Senior Research Fellow, mmolodchik@hse.ru

Iuliia Naidenova

Deputy Head, yunaydenova@hse.ru

Evgeniya Shenkman

Junior Research Fellow, ea_popova@hse.ru

Egor Ivanov

Research Assistant, EA.Ivanov@hse.ru

International Laboratory of Intangible-driven Economy, National Research University Higher School of Economics, Perm campus, 614070, Perm, blv. Gagarina 37

Abstract

The study investigates the Russian information and communication technologies (ICT) landscape with a focus on sustainable ICT combinations at the industry level. The ICT combination for a company reflects its ICT profile, which is considered in resource theory as the firm's ability to create competitive advantages based on resource complementarity. Unlike previous papers, it is not an expert-specified combination of ICT that is being studied, but a tool for the automated search for interconnected technologies based on machine learning methods is proposed, which makes it possible to identify stable combinations implemented simultaneously by several companies in a certain industry. ICT profile identification was conducted based on the analysis of relationships across a wide range of IT, from basic infrastructure to AI-based business efficiency management systems. The final dataset includes 110 IT technologies for over 29,000 companies from 31 industries spanning from 2006 to 2022. The following conclusions were drawn: (1) a typical profile for most industries consists of a combination of business process management (BPM) and software as a service (SaaS), (2) insurance and finance industries are the leaders in the diversity and complexity of ICT profiles, (3) supplementing ICT profiles with AI-based solutions holds great potential for Russian companies, (4) the implementation of ICT profiles is linked to companies' financial performance; however, these relationships vary significantly across industries.

Introduction

Information and communication technologies (ICT) make a critical contribution to the digitalisation of the economy, while their efficient application is a vital condition for economic growth (Karim et al., 2022). Numerous studies demonstrated the important role ICT play in the development of countries (Habibi, Zabardast, 2020) and companies (Chae et al., 2018; Li et al., 2022), along with such traditional factors as labour and capital.

ICT refers to a very wide range of technologies from basic infrastructure to artificial intelligence-based business performance management systems, leading to the high variability of corporate ICT architectures. Recent studies highlight the growing importance of ICT in the implementation of advanced solutions such as cross-cutting AI technology (Agarwal et al., 2021; Enholm et al., 2022; Dumas et al., 2023), and the shortcomings of traditional approaches to assessing their effectiveness. E.g. when ICT investment data is summarised (Mithas, Rust, 2016), or the contribution of particular technologies is assessed (HassabElnaby et al., 2012; Daviy, 2023), correlation between these technologies is often ignored. Problems with ICT integration are major barriers hindering effective implementation of new technologies (Xue et al., 2005; Amid et al., 2012; Coşkun et al., 2022). Empirical studies increasingly reveal insignificant or even negative impact of certain ICTs on company performance, attributing this to the waste of relevant costs due to various circumstances or particular combinations of resources.

Few previous empirical studies attempted to take into account the heterogeneity of ICTs, and assess their overall performance. This is largely due to the lack of detailed corporate data on ICT adoption, since its disclosure could be used by competitors to their advantage. Some studies (Hendricks et al., 2007; Oh, Kim, 2023) did consider the benefits of applying several ICTs in combination, but the lists of analysed technologies were drafted by experts, and thus may not reflect the actual practices. The analytical approach based on considering not just individual ICTs, but their combinations was implemented in (Wu et al., 2015; Geum et al., 2015): the authors searched for association rules, which allows to objectively identify technology combinations based on actual data.

The goal of this paper is to identify stable ICT combinations, or ICT profiles applied by Russian companies, and assess their effectiveness on the basis of financial indicators. Another objective is to consider the identified ICT profiles in terms of their potential for implementing AI-based solutions. By a stable ICT combination we mean a set of technologies simultaneously implemented by multiple companies. To describe the situation with ICT implementation as thoroughly as possible, e.g. in a particular industry, we identify three types of ICT profiles which can potentially make the greatest impact on the company's performance. Firstly, it's the most common combination of ICTs without which companies supposedly won't be able to do business. E.g. existing studies show that if a company doesn't apply Enterprise Resource Planning (ERP) technology, its use of other resources will be less than efficient (Shakina et al., 2022). The second ICT profile type comprises the widest range of technologies, indicating a high technological level and penetration of ICTs into various aspects of business. The broader the scope of an ICT profile, the more likely the company to be an ICT leader, which serves as a source of its competitive advantage (Chae et al., 2014). Thirdly, ICTs must be industry specific (Jacobsson et al., 2017).

The identified ICT profiles allow to comprehensively describe commonly used ICT combinations as the basis for developing multi-technology solutions for companies in particular industries. Also, analysing the technology combinations companies need to operate smoothly allows to identify the ICTs adopting which is critical in terms of withstanding market shocks. For Russian companies, the departure of many major foreign vendors such as SAP, Oracle, or Microsoft certainly became a major shock. Also important is to identify commonly used inefficient ICT profiles, to prevent the application of outdated technologies or avoid systemic ICT integration problems.

ICT combinations through the prism of the resource approach

Theoretical studies of ICT systems usually tend to apply the resource-based approach (Barney et al., 2001), which defines ICT as companies' strategic resources for obtaining a competitive advantage. Fundamentally important here is not so much the availability of valuable and unique resources as the organisation's ability to combine them on the basis of their internal potential and availability. Finding the optimal combination of resources to achieve a synergy from their use is a key objective of present-day management (Teece, 2018; Shakina et al., 2022). In this regard, ICT in general, and specific systems in particular are seen as parts of the company's resource portfolio, to be used jointly with its other parts. However, only a small number of studies are focused on the complementarity of specific ICTs (Geum et al., 2015; Wu et al., 2015; Díaz-Chao et al., 2021), while the ability to intelligently combine them in a single corporate portfolio becomes a source of competitive advantage (Geum et al., 2015).

In this paper we consider ICT combinations as profiles comprising technologies simultaneously applied in the course of company operations. In the scope of the resource-based approach, an ICT profile is a combination of resources reflecting the organisation's strategic ability to manage its competitive advantages. The decision to use multiple technologies can be driven by a variety of factors.

An ICT profile can be a key resource combination underlying a business model, and a source of profit for the company (Teece, 2018). Several complementary ICTs can be applied to accomplish production-related objectives in a more efficient way. It should be noted that the technologies' relationship in the scope of a profile doesn't necessarily have to be of a complementary nature: some of them may be related to other company resources, generating synergies with them. Good examples of such complementarity are the implementation of ICT systems such as ERP and BI (Gupta et al., 2019), or the combination of IoT and BigData. In recent years, individual ICT systems' functionality was steadily extending due to the use of AI. E.g. CraftTalk's BSS Digital2Speech integrates AI into an ICT profile which includes CRM, biometric identification, and speech technologies.

Three vectors of complementing existing ICT systems with AI are generally seen as the most promising ones (Enholm et al., 2022):

1) computer vision: image, photo, and video recognition, analysis, and classification;

2) natural language processing: text generation, sentiment analysis, and perception of information created by others;

3) machine and deep learning: clustering, classification, and integration into recommendation systems.

Companies' choice of an ICT profile is largely determined by the specifics of their industry. The differences are related to the role of ICT in particular industries (Jacobsson et al., 2017; Chae et al., 2018): in some, ICT provides an alternative to human labour, i.e. it's applied to automate business processes; in others it plays an informational role providing data and supporting management decisions; in others still, it performs a transformational function, fundamentally transforming business models, industry mechanisms, and the interaction of economic agents. An additional argument in favour of the suggested approach is the different levels of industries' digitalisation, clearly reflected in statistics.

Industry affiliation allows to assess the impact of companies' ICT profiles on their performance. Evaluating profiles' effect is similar to measuring the costs and benefits of using ICT capital, or indi-

vidual ICT systems. The risks associated with using several resources simultaneously include system incompatibility, different time required to integrate them into the company's infrastructure, different support modes, etc. (Coşkun et al., 2022). A review of empirical studies shows that the productivity of ICT combinations was analysed without taking into account industry specifics, while the actual combinations were suggested by experts (such as, e.g., ERP or BI). Given the theoretically substantiated contribution of ICT profiles to companies' competitive advantage, there is a need to test these profiles' impact on company performance in various industries. This, in turn, implies evaluating the use of ICT profiles in relevant industries, namely how many companies use a particular profile, i.e. how common is a particular combination of technologies.

At the industry level, we distinguish three ICT profile types: typical, complex, and specific. The first refers to the most common ICT combination in the industry; the second, to the biggest and most widely used combination, i.e. the one comprising the largest number of technologies and applied by the largest number of companies operating in the industry; the third type reflects a unique combination of technologies not encountered in other industries. Typical profiles act as a kind of industry standard; complex ones are applied by companies implementing innovative ICT strategies (Devece et al., 2017); specific profiles can be used to accomplish unique objectives arising in a particular industry. In the practical part of our study, all three profile types will be assessed in terms of the potential to extend ICT functionality with the help of AI.

Research methodology

An AI tool was used to identify stable ICT combinations: an algorithm for searching for association rules, proposed by (Agrawal et al., 1993) and actively applied in various sectors of the economy including the financial sector (Batarseh et al., 2021; Kaur, Dharni, 2022). Essentially, the algorithm searches for association rules of the kind "the company implemented both ICT X and ICT Y" (Hegland, 2003). Quality metrics (support, confidence, and lift) can be calculated for each rule, based on the frequency of its (or its individual elements) occurrence in the available data array. However, each rule has certain specifics.

1) ICT X support is the share of companies in the sample which have implemented technology X; in a way it shows how frequently the technology is used, or its popularity; rule X→Y support is the share of companies which have adopted both ICT X and ICT Y.

2) Rules' credibility is calculated as the ratio of rule $X{\rightarrow}Y$ support to the share of companies which have implemented ICT X; it reflects the probability of adopting ICT Y if ICT X has already been implemented.

3) The rule's lift, or the metric of its importance, reflects how often the share of companies which have implemented both ICT X and ICT Y exceeds the share of expected implementations when there is no correlation between adopting ICT X and ICT Y; if this metric's value is greater than 1, it means ICTs X and Y complement each other. In line with our hypothesis that ICT profile should comprise complementary technologies, only association rules with the lift value above 1 were considered in the further analysis.

At the next methodological step, the *Apriori* algorithm (Agrawal et al., 1994) was applied: it's a classic mechanism for sorting out a set of possible association rules. It's a part of an integrated strategy for selecting potential candidates for inclusion in stable association rules, the so-called. apriori principle (Hegland, 2003). The result significantly depends on the threshold values set for the support and credibility metrics: if they are close to 0, the algorithm will identify a large number of rules which, on the one hand, might make the subsequent analysis labour-intensive, but on the other, reveal productive and non-trivial stable rules. If the threshold values are set close to the upper limit, the algorithm will work faster and yield a small number of rules; however, these may turn out to be banal and self-evident (Hegland, 2003; Hikmawati et al., 2021).

No universal algorithms for determining optimal threshold values have been developed yet. In most cases researchers set them empirically for each particular task, taking into account the sample size and the maximum number of rules they are willing to process (Kotsiantis, Kanellopoulos, 2006). E.g. it was experimentally demonstrated that for different data on different domains, optimal support threshold values can vary between 0 and 60% (Hikmawati et al., 2021). However, several patterns emerge here: the larger the data array, the lower the support threshold value should be; and the broader the range of ICTs, the lower the support and credibility thresholds should be set.

As a starting point for setting minimum optimal support and credibility levels, we followed the logic of previous studies in a related research area. E.g. (Wu et al., 2015) set the support threshold at 10%, and (Geum et al., 2015) at 3%; the credibility thresholds were set at 50% and 40%, respectively. Because our sample covers a broader range of ICTs than in previous studies, lower threshold values can be used. Empirically, we settled on 1.5% for the support metric, and 25% for credibility.

An important criterion for searching for associative rules of ICT application is the period during which ICTs should be considered as applied by the company together. A short period (e.g. 1 year) will yield a small number of such combinations; while setting a too long duration would increase the risk the combinations would comprise already abandoned technologies which have not actually been used in conjunction with each other. Therefore using a "sliding window" to cover the period of technology application appears to be a more effective approach. Its duration should be set taking into account the rate of ICT systems' implementation, and their service life in the relevant industry. Since in this study the average observation period for companies' activities was 1.5 years, the search for association rules was carried out for its entirety.

To validate the identified ICT profile types, and assess the effectiveness of existing industry practices, we measured the impact of adopting such profiles on company performance. The following fixed effects model was applied, for each industry separately:

$$y_{i,t,s} = \alpha_{0,s} + \alpha_{1,s} * size_{i,t-1,s} + \alpha_{2,s} * leverage_{i,t-1,s} + \sum_{j=1}^{k} \beta_{j,s} * Profile_{j,i,t,}s + \psi_{i,s} + \mu_{t,s} + \epsilon_{i,t,s}, \qquad (1)$$

where y is performance indicators of company i in industry s in year t, with $s = 1.31$.

Labour productivity and profit margins were used as company performance indicators. Since implementing and combining technologies requires significant investment, their impact on labour productivity was seen as an intermediate indicator, and on profit margins as resulting one. Therefore equation (1) was calculated for the relevant company performance indicators separately for each of the 31 industries. In such models, company size $sise_{i,t-1}$ (in our case, the logarithm of company assets was applied as a proxy for this indicator), and financial leverage $leverage_{i,t-1}$ (calculated as the ratio of borrowed capital to company assets) are most often used as control indicators (Enekwe et al., 2014; Zavertiaeva et al., 2020). Control indicators were applied with a one-year lag, to address the potential reverse causality problem (Bellemare et al., 2017; Hill et al., 2021). To take into account individual characteristics of companies and macroeconomic conditions, company and yearly fixed effects were also added to the equation, denoted as ψ_i and μ_t, respectively.

The variable $Profile_{j,i,t}$ coefficient is of key interest. This variable reflects the application of the j-th ICT profile by the i-th company in the year t. Technically, it's a dummy variable that takes only two values: 1 and 0. The index k denotes the number of ICT

profiles in the industry; generally there are three: specific, complex and typical. Since it was not possible to identify a specific ICT profile for certain industries, the index *k* for them was set to 2. The coefficient reflects the contribution of profile *j* to company performance $y_{i,t}$.

Empirical basis of the study

To check the presence of stable relationships between ICTs, a database was created comprising more than 29 thousand companies operating in 31 industries, which implemented ICT systems in 2006-2022. TAdviser was used as the main data source - the largest aggregator of news about ICT manufacturers, the actual technologies, and their implementation in Russia. The data was supplemented with information from company websites. The analysis covered more than 100 technologies. The list of those included in the ICT profiles of Russian firms is presented in Appendix 1.

Data analysis showed that on average, Russian companies use two ICTs, although the maximum per company number, e.g. in the financial industry, can be as high as 71. In general, we can note a high heterogeneity of domestic businesses in terms of the number of ICTs implemented. Despite the long observation period, the average per company duration was 1.5 years. The effect of using particular ICT profiles was assessed on the basis of available SPARK system data, taking into account the comparability of data from different sources. Table 1 presents descriptive statistics on financial indicators by industry, included in the model described by equation (1).

Identified ICT profiles of Russian companies

ICT profiles of Russian companies operating in various industries were identified with the help of the association rules method. The matrix presented in Fig. 1 reflects the characteristics of various industries' technology landscape in terms of the average diversity and complexity of applied ICT profiles. Diversity was measured as the number of stable technology combinations, and complexity as the size of the ICT profile, i.e. the number of technologies used in combination with each other. The circle size on the graph below reflects the technological level of the relevant industry derived from the average number of ICTs applied per company.

The high diversity and complexity of the applied ICT profiles may be evidence of a developed industry ICT architecture. The undisputed leaders by this criterion are insurance (INS) and financial services (FIN). The same quadrant also includes public ad-

ministration (SOC), steam, gas and electricity supply (ENR), oil production and refining (OIL), metallurgical production (MET), ICT (INT), and mining of other minerals (MIN). At the opposite end are the industries with homogeneous ICT profiles comprising a small set of technologies: activities of public organisations (PUB), hospitality (TOU), etc., located in the lower left-hand quadrant of the matrix (Fig. 1). Despite the apparent positive relationship between the diversity and complexity of ICT profiles at the industry level, one can see that two industries have predominantly homogeneous profiles comprising a wide range of ICTs, namely management consulting (CST) and legal services (JUR).

In the course of further analysis, ICT profile types were considered. Table 2 presents ICT combinations for each industry, which reflect ICT profile categories. Additional analysis of the use of AI-based solutions allowed to identify industries and ICTs already using such tools. In Table 2, AI-based ICTs are shown in italics (if the industry companies use relevant products). For some industries, no unique stable combination was found, i.e. they have no industry-specific profile.

Cross-industry comparison of the identified ICT profiles reveals similarities in technology application (in particular, BPM, CRM, EDMS and SaaS) due to their general-purpose nature. E.g. many companies strive to automate client serving operations and implement CRM systems; almost all of them use EDMS; many have a need to optimise business processes with the help of BPM systems; the SaaS format offers numerous software products provided through outsourcing, including cloud
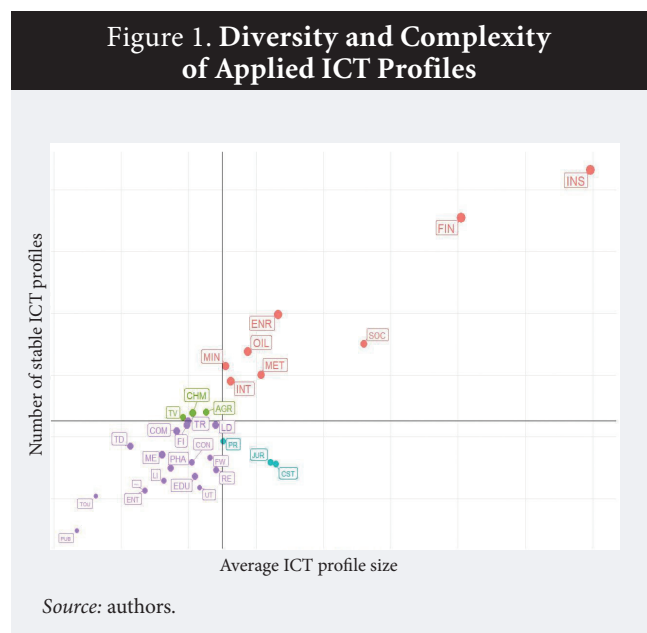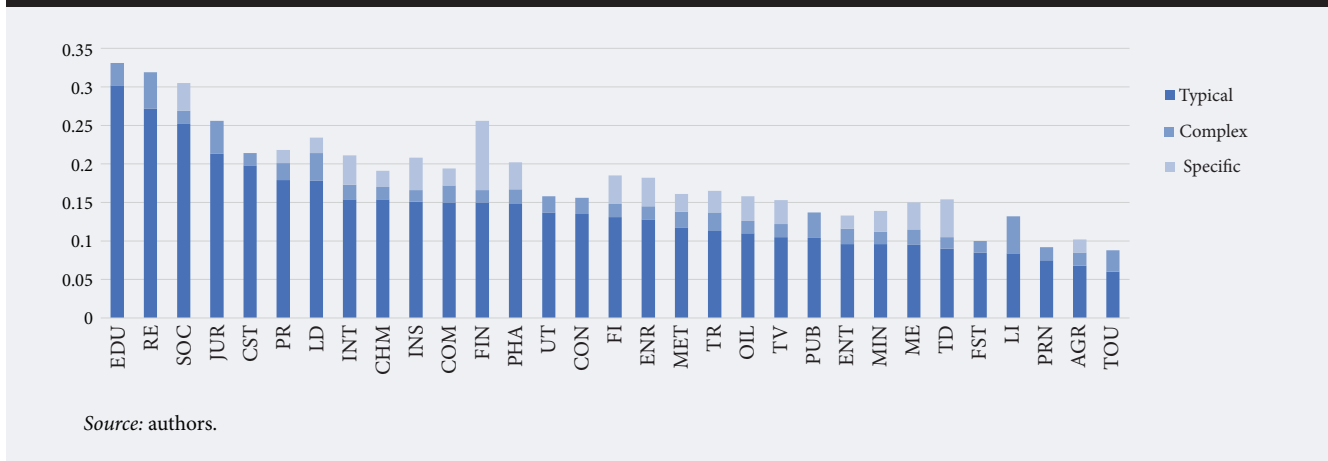

Figure 1. **Diversity and Complexity of Applied ICT Profiles**

Source: authors.

Figure 2. **ICT profile application by industry**

Source: authors.

computing. However, the above solutions are combined with industry-specific complementary technologies. In the oil industry, it's satellite communications and navigation which may be required because oil fields are frequently located in remote areas; in the public sector it's data mining, since government organisations often deal with citizen requests which are a source of large amounts of data. The combined use of management technologies (ERP, WMS, HRM, CRM) and data analysis (BI, data centres, big data) should also be noted. The above-mentioned technologies are integrated to support corporate decision-making.

The adoption rate of ICT profiles significantly varies between industries (see Fig. 2). E.g. in education, typical profile is implemented by 30% of organisations, while in mining of other minerals only by 6%. Other profile types are implemented much less frequently: complex profiles by between 1.5% and 5% of companies, and specific profiles are applied only in 20 industries (the largest share (9%) was found in financial services).

Analysis of the implementation of AI-based solutions by domestic companies revealed that not all ICT profiles comprise such tools, which indicates they have a high potential to promote digitalisation of Russian businesses. The leaders here are financial services, investments, and audit; these industries have implemented about 40 EDMS projects (stream recognition systems, EDS-SRS). According to the TAdviser portal, most such solutions on the Russian market are supplied by Smart Engines. Integrating AI tools into BPM systems has good prospects. We did not find in the publicly available sources any information about Russian companies which have actually implemented such solutions, but AI-supplemented BPM systems are available

on the market (e.g. Sherpa RPA by Sherpa Robotics). Such tools allow to adapt and improve business processes by making them context-sensitive, and facilitate human-machine interaction (Dumas et al., 2023).

Effect of ICT profiles' application, by industry

The impact of ICT profiles on companies' profit margins and productivity was measured in line with equation (1). The calculations show that the correlation between using a typical ICT profile and profit margins is non-linear. Figure 3 presents data on the significant correlations between various ICT profile types and firms' profit margins, normalised to the industry average.

If in ICT industry, oil industry, and public administration the correlation under consideration is positive, in metallurgy, telecommunications, construction, and production of consumer goods it's negative. The negative impact can be explained by the widespread use of outdated or poorly integrated technologies, so upgrading ICT seems to be a most relevant task for these industries. The success of leading metallurgical firms is largely due to the implementation of the entire range of ICT profile technologies, which provides a good example for companies using ineffective typical profiles. However, in real estate, mining, and ICT the latter profile type turned out to affect company performance positively.

As to complex ICT profiles, a positive correlation with companies' profit margins was established in metallurgy, transport, healthcare, and energy, though the introduction of these technologies does

Industry	ROS, %	Productivity, *million roubles/person*	Leverage	Assets, *million roubles*
Maintenance of buildings and premises	1.73	28.94	2.26	6519.80
Creative activities (arts and entertainment)	1.74	12.45	2.08	5219.16
ICT	12.71	12.87	0.50	13446.05
Management consulting	5.39	11.74	1.27	2779.34
Light industry	6.17	20.21	1.62	4016.07
Warehouse services	7.50	26.66	1.78	17055.34
Manufacturing of machinery and equipment	2.86	17.07	1.65	16467.56
Metallurgical production	4.32	15.64	1.78	41925.21
Real estate operations	7.28	171.16	13.35	58632.51
Oil production and refining	8.09	36.55	1.20	146273.52
Education	9.27	4.94	0.16	3445.40
Activities of public organisations	5.96	1.63	0.43	8957.94
Food production	4.85	15.59	1.92	8189.67
Publishing	7.81	7.48	1.28	2919.09
Advertising	8.83	27.43	2.54	3043.29
Agriculture	5.62	16.05	0.38	8563.28
Telecommunications	5.66	17.49	3.66	17830.27
Insurance	18.67	44.21	0.54	668588.91
Construction	3.68	26.81	2.00	13558.71
Production of consumer goods	4.64	14.88	1.33	5895.65
Trade	2.64	74.66	1.92	24118.76
Public administration	14.21	4.82	0.03	30318.63
Transportation and storage	7.39	33.41	1.86	19915.37
Hospitality	18.84	7.57	2.09	741.13
Healthcare	7.52	21.77	1.01	10625.07
Financial services	8.05	131.80	5.59	45617.59
Chemical production	8.43	13.04	1.20	15696.13
Steam, gas and electricity supply	3.13	24.80	0.98	28610.29
Legal services	15.68	10.67	0.66	2773.82
Mining of other minerals	6.08	18.00	1.71	70840.78
Total for the sample	**7.49**	**29.01**	**1.96**	**1302584.36**

Source: authors.

not affect productivity (except in the construction industry). Therefore one can assume that improved performance is due to reduced costs and better decisions, not to personnel layoffs.

Analysis of specific industries revealed that in metallurgy, the typical profile technologies (BPM and SaaS) are included in the complex one, which comprises BPM, SaaS, CRM, and EDMS. This emphasises the advisability of adopting the latter two technologies for metallurgical firms. This result may be explained by the fact that better-performing companies have more financial resources to implement the technologies in question. In healthcare and energy, the situation is somewhat different: there's no negative correlation between profit margins and the use of typical profile which combines such core technologies as video conferencing and SaaS. More successful players in addition to SaaS also use management tools. In healthcare the relevant technologies are BPM, CRM, EDMS, while in the energy sector it's ERP, HRM, EDMS, and EDMS-SPR. I.e. in these industries the most common, the typical profile comprises a set of necessary technologies, which, on the other hand, does not allow firms to get ahead of their competitors. A similar situation is observed in the transport sector, where the typical ICT profile comprises safety and vehicle control technologies, satellite communications and navigation, the use of which does not affect profit margins (unlike the adoption of complementing systems such as TMS, logistics information system, and FMS which makes a positive impact on this indicator).
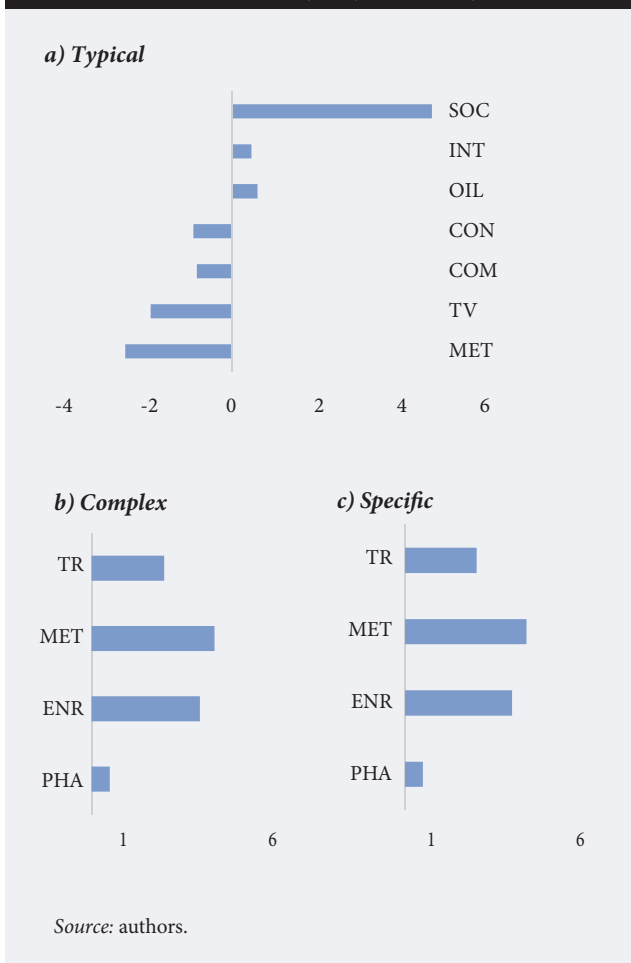
In the ICT industry, the typical profile includes BPM and SaaS, and its use is positively correlated with both company productivity and profitabil-

Table 2. **ICT profiles by industry**				
Industry	**Code**	**Typical**	**Complex**	**Specific**
Maintenance of buildings and premises	UT	BPM, SaaS	BPM, CRM, SaaS, EDM	
Creative activities (arts and entertainment)	ENT	BPM, SaaS	BPM, HRM, SaaS, EDM	VSS, PACS
ICT	INT	BPM, SaaS	BPM, CRM, SaaS, IS, DC	Cloud Computing, IaaS, PaaS
Management consulting	CST	BPM, SaaS	BPM, CRM, ITSM, SaaS, EDM	
Light industry	LI	BPM, SaaS	IS, EDM, SRS	
Forestry and forest industry	FST	SaaS, WMS	BPM, ERP, SaaS, EDM	
Warehouse services	LD	WMS, LIS	TMS, LIS, BPM, FMS, SCN	BPM, SaaS, WMS
Manufacturing of machinery and equipment	ME	BPM, SaaS	BPM, CRM, SaaS, EDM	PDM, PLM
Metallurgical production	MET	BPM, SaaS	BPM, CRM, ITSM, SaaS, EDM	BI, EAM, ERP
Real estate operations	RE	BPM, SaaS	BPM, HRM, SaaS, EDM	
Oil production and refining	OIL	ERP, SaaS	TMS, BPM, FMS, SCN, EDM	ERP, SCN
Education	EDU	SaaS, WMS	BPM, HRM, SaaS, EDM	
Activities of public organisations	PUB	SaaS, WMS	BPM, CRM, SaaS	
Food production	FI	ERP, SaaS	CRM, ERP, ATS, accouting systems	CRM, ATS
Publishing	PRN	ERP, SaaS	Call centres, CMS, CRM, accounting systems	
Advertising	PR	BPM, SaaS	BPM, CRM, ITSM, SaaS, EDM	CRM, HRM, PMS
Telecommunications	AGR	BPM, SaaS	ITSM, SaaS, IS, ICT outsourcing	Server platforms, data centres
Agriculture	TV	BPM, SCN	TMS, LIS, VST, FMS, satellite communications and navigation	Robotics, RBL
Insurance	INS	BPM, EDM	BI, CPM, CRM, ERP, HRM, IS, corporate portals, EDM, accounting systems	Corporate portals, SRS
Construction	CON	BPM, SaaS	TMS, VST, FMS, satellite communications and navigation	
Production of consumer goods	COM	ERP, SaaS	BI, Data Mining, Data Quality, OLAP	BI, OLAP, WMS
Trade	TD	BPM, SaaS	SCM, SRM, WMS	WMS, ATS
Public administration	SOC	SaaS, WMS	BI, Big Data, BPM, Data Mining, ERP, SCM, SRM	Digitalisation of public administration, corporate portals
Transportation and storage	TR	VST, SCN	TMS, LIS, BPM, FMS, SCN	Call centres, OSS/BSS
Hospitality	TOU	ATS, accounting systems	BPM, SaaS, EDM	
Healthcare	PHA	SaaS, WMS	BPM, CRM, SaaS, EDM	ERP, MIS
Financial services	FIN	BPM, SaaS	BI, CRM, SaaS, BI, ICT outsourcing, RBS, EDM	SaaS, RBS
Chemical production	CHM	ERP, SaaS	BPM, CRM, SaaS, EDM	MES, WMS
Steam, gas and electricity supply	ENR	SaaS, WMS	ERP, HRM, SaaS, EDM, SRS	ERP, Automated commercial electricity metering system
Legal services	JUR	BPM, SaaS	BPM, CRM, ITSM, SaaS, EDM	
Mining of other minerals	MIN	SaaS, EDM	BI, ERP, HRM, SaaS, EDM	ERP, LIS
Source: authors.				

Figure 3. **Normalised assessment of the impact of companies' ICT profiles on their profitability, by industry**

a) Typical

b) Complex

c) Specific

Source: authors.

- conclude that analysing companies' ICT profiles by industry, taking into account the specifics of their ICT architecture and the role of particular technologies in company operations, is a productive approach;

- suggest a classification of ICT profiles by their popularity, complexity, and uniqueness for specific industries; the classification comprises typical, complex, and specific profile types.

The methodological result of the study is adapting the association rules method to identify ICT profiles at the industry level, including substantiating the "support" and "credibility" levels.

The key empirical results include the following. Analysis of the diversity and complexity of ICT profiles revealed significant heterogeneity of the domestic corporate landscape in terms of the use of stable ICT combinations in various industries. This confirms the need to take into account industry specifics when designing state programmes to promote digital transformation of the economy. On average, companies use two ICT systems, so typical ICT profile includes BPM and SaaS systems. The use of AI-based solutions by Russian companies has not yet become sufficiently widespread, which allows us to highlight this vector as a promising business digitalisation path. Analysis of the success of adopting various ICT profiles in terms of increasing company productivity and profit margins did not yield clear results.

The theoretical and empirical conclusions of the paper can help increase digital maturity and the quality of Russian companies' digital transformation, which matches the objectives of the national programme "Digital Economy of the Russian Federation". Our full-scale study of domestic companies' ICT profiles based on data on more than 29 thousand firms operating in 31 industries allowed to identify three stakeholder groups. The first comprises ICT suppliers who will be able to identify potential market niches and opportunities for promoting multi-tech products. The second target group is industry players themselves, who will be able to compare their ICT profile with the one typical for their industry, evaluate their competitive environment, consider alternative technology combinations, most relevant offers on the ICT solutions market, and possible ways to optimise the use of ICT based on benchmarks. This, in its turn, should help promote demand for ICT products and technologies. The third target group is the academic community specialising in studying technology management and corporate economics. Of greatest interest to this group are empirically tested stable ICT combinations which reflect industry specifics, and the correlation of their use with companies' financial results.

ity. This technology combination supposedly contributes to more efficient use of human resources. Adoption of typical profile in real estate (BPM and SaaS) and mining (EDS and SaaS) increases productivity even compared to companies implementing more advanced complex profiles. However, a more efficient use of labour resources does not lead to increased profit margins.

Thus, ICT profiles and their types do affect companies' financial performance, but this relationship varies between different industries.

Conclusion

The study demonstrated the advisability of considering companies' stable ICT profiles in theoretical and practical terms; these profiles are understood as combinations of technologies applied together, which become a source of competitive advantage due to resource complementarity. The resource theory allowed us to obtain two theoretical results:

The limitations of the study include the reluctance of many Russian companies to disclose information about their implementation of ICT systems. The paper is based on open data posted on the internet, which does not exclude the possibility that in reality ICT systems, including AI-based ones, are used more broadly. The prospects of further research include studying the dynamics of ICT profiles, and identifying the reasons for the financial failure of some of them in certain industries. Annual moni-toring of Russian companies' ICT profiles can be of a practical use for investors and financial institutions as an analytical tool. Companies could conduct such monitoring to plan long-term growth, which would help achieve sustainability and transparency.

The study was conducted in the framework of the strategic National Research University Higher School of Economics project "Digital transformation: technologies, effects, efficiency."

References

Agarwal G.K., Magnusson M., Johanson A. (2021) Edge AI Driven Technology Advancements Paving Way Towards New Capabilities. *International Journal of Innovation and Technology Management*, 18(01), 2040005. https://doi.org/10.1142/S0219877020400052

Agrawal R., Imieliński T., Swami A. (1993) *Mining association rules between sets of items in large databases*. Paper presented at the 1993 ACM SIGMOD International Conference on Management of Data, June 1993. https://doi.org/10.1145/170035.170072

Agrawal R., Srikant R., Road H., Jose S. (1994) *Fast Algorithms for Mining Association Rules*. Paper presented at the 20th International Conference on Very Large Data Bases (VLDB), September 12–15, 1994, Santiago de Chile, Chile.

Amid A., Moalagh M., Zare Ravasan A. (2012) Identification and classification of ERP critical failure factors in Iranian industries. *Information Systems*, 37(3), 227–237. https://doi.org/10.1016/j.is.2011.10.010

Barney J., Wright M., Ketchen D.J. (2001) The resource-based view of the firm: Ten years after 1991. *Journal of Management*, 27(6), 625–641. https://doi.org/10.1177/014920630102700601

Batarseh F.A., Gopinath M., Monken A., Gu Z. (2021) Public policymaking for international agricultural trade using association rules and ensemble machine learning. *Machine Learning with Applications*, 5, 100046. https://doi.org/10.1016/j.mlwa.2021.100046

Bellemare M.F., Masaki T., Pepinsky T.B. (2017) Lagged Explanatory Variables and the Estimation of Causal Effect. *The Journal of Politics*, 79(3), 949–963. https://doi.org/10.1086/690946

Chae H.-C., Koh C.E., Prybutok V.R. (2014) Information Technology Capability and Firm Performance: Contradictory Findings and Their Possible Causes. *MIS Quarterly*, 38(1), 305–326. https://doi.org/10.25300/MISQ/2014/38.1.14

Chae H.-C., Koh C.E., Park K.O. (2018) Information technology capability and firm performance: Role of industry. *Information & Management*, 55(5), 525–546. https://doi.org/10.1016/j.im.2017.10.001

Coşkun E., Gezici B., Aydos M., Tarhan A.K., Garousi V. (2022) ERP failure: A systematic mapping of the literature. *Data & Knowledge Engineering*, 142, 102090. https://doi.org/10.1016/j.datak.2022.102090

Daviy A. (2022) Does the regional environment matter in ERP system adoption? Evidence from Russia. *Journal of Enterprise Information Management*, 36(2), 437–458. https://doi.org/10.1108/JEIM-11-2021-0488

Devece C., Palacios-Marqués D., Galindo-Martín M.-Á., Llopis-Albert C. (2017) Information Systems Strategy and its Relationship with Innovation Differentiation and Organizational Performance. *Information Systems Management*, 34(3), 250–264. https://doi.org/10.1080/10580530.2017.1330002

Díaz-Chao Á., Ficapal-Cusí P., Torrent-Sellens J. (2021) Environmental assets, Industry 4.0 technologies and firm performance in Spain: A dynamic capabilities path to reward sustainability. *Journal of Cleaner Production*, 281, 125264. https://doi.org/10.1016/j.jclepro.2020.125264

Dumas M., Fournier F., Limonad L., Marrella A., Montali M., Rehse J.-R., Accorsi R., Calvanese D., De Giacomo G., Fahland D., Gal A., La Rosa M., Völzer H., Weber I. (2023) AI-Augmented Business Process Management Systems: A Research Manifesto. *ACM Transactions on Management Information Systems*, 14(1), 1–19. https://doi.org/10.1145/3576047

Enholm I.M., Papagiannidis E., Mikalef P., Krogstie J. (2022) Artificial intelligence and business value: A literature review. *Information Systems Frontiers*, 24(5), 1709–1734. https://doi.org/10.1007/s10796-021-10186-w

Enekwe C., Agu C., Nnagbogu E. (2014) The Effect of Financial Leverage on Financial Performance: Evidence of Quoted Pharmaceutical Companies in Nigeria. *IOSR Journal of Economics and Finance*, 5(3), 17–25. https://doi.org/10.9790/5933-0531725

Geum Y., Lee H., Lee Y., Park Y. (2015) Development of data-driven technology roadmap considering dependency: An ARM-based technology roadmapping. *Technological Forecasting and Social Change*, 91, 264–279. https://doi.org/10.1016/j.techfore.2014.03.003

Gupta S., Qian X., Bhushan B., Luo Z. (2019) Role of cloud ERP and big data on firm performance: A dynamic capability view theory perspective. *Management Decision*, 57(8), 8. https://doi.org/10.1108/MD-06-2018-0633

Habibi F., Zabardast M.A. (2020) Digitalization, education and economic growth: A comparative analysis of Middle East and OECD countries. *Technology in Society*, 63, 101370. https://doi.org/10.1016/j.techsoc.2020.101370

HassabElnaby H.R., Hwang W., Vonderembse M.A. (2012) The impact of ERP implementation on organizational capabilities and firm performance. *Benchmarking: An International Journal*, 19(4/5), 618–633. https://doi.org/10.1108/14635771211258043

Hegland M. (2003) Algorithms for Association Rules. In: *Advanced Lectures on Machine Learning: Machine Learning Summer School 2002 Canberra, Australia, February 11–22, 2002, Revised Lectures* (eds. S. Mendelson, A.J. Smola), Heidelberg, Dordrecht, London, New York: Springer, pp. 226–234. https://doi.org/10.1007/3-540-36434-X_7

Hendricks K.B., Singhal V.R., Stratman J.K. (2007) The impact of enterprise systems on corporate performance: A study of ERP, SCM, and CRM system implementations. *Journal of Operations Management*, 25(1), 65–82. https://doi.org/10.1016/j.jom.2006.02.002

Hikmawati E., Maulidevi N.U., Surendro K. (2021) Minimum threshold determination method based on dataset characteristics in association rule mining. *Journal of Big Data*, 8(1), 146. https://doi.org/10.1186/s40537-021-00538-3

Hill A.D., Johnson S.G., Greco L.M., Walter S.L. (2021) Endogeneity: A Review and Agenda for the Methodology-Practice Divide Affecting Micro and Macro Research. *Journal of Management*, 47(1), 105–143. https://doi.org/10.1177/0149206320960533

Jacobsson M., Linderoth H.C.J., Rowlinson S. (2017) The role of industry: An analytical framework to understand ICT transformation within the AEC industry. *Construction Management and Economics*, 35(10), 611–626. https://doi.org/10.1080/01446193.2017.1315148

Karim M.S., Nahar S., Demirbag M. (2022) Resource-Based Perspective on ICT Use and Firm Performance: A Meta-analysis Investigating the Moderating Role of Cross-Country ICT Development Status. *Technological Forecasting and Social Change*, 179, 121626. https://doi.org/10.1016/j.techfore.2022.121626

Kaur J., Dharni K. (2022) Assessing efficacy of association rules for predicting global stock indices. *DECISION*, 49(3), 329–339. https://doi.org/10.1007/s40622-022-00327-8

Kotsiantis S., Kanellopoulos D. (2006) Association rules mining: A recent overview. *GESTS International Transactions on Computer Science and Engineering*, 32(1), 71–82.

Li L., Tong Y., Wei L., Yang S. (2022) Digital technology-enabled dynamic capabilities and their impacts on firm performance: Evidence from the COVID-19 pandemic. *Information & Management*, 59(8), 103689. https://doi.org/10.1016/j.im.2022.103689

Mithas S., Rust R.T. (2016) How Information Technology Strategy and Investments Influence Firm Performance: Conjecture and Empirical Evidence. *MIS Quarterly*, 40(1), 223–245. https://doi.org/10.25300/MISQ/2016/40.1.10

Oh I., Kim J. (2023) Frontiers and laggards: Which firms benefit from adopting advanced digital technologies? *Managerial and Decision Economics*, 44(2), 753–766. https://doi.org/10.1002/mde.3710

Shakina E., Naidenova I., Barajas A. (2022) Shadow prices for intangible resources. *Journal of Intellectual Capital*, 23(3), 666–686. https://doi.org/10.1108/JIC-02-2020-0031

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

Wu Y.-C.J., Dong T.-P., Chang C.-L., Liao Y.-C. (2015) A collaborative learning lesson from using effective information technology combinations. *Computers in Human Behavior*, 51, 986–993. https://doi.org/10.1016/j.chb.2014.10.008

Xue Y., Liang H., Boulton W.R., Snyder C.A. (2005) ERP implementation failures in China: Case studies with implications for ERP vendors. *International Journal of Production Economics*, 97(3), 279–295. https://doi.org/10.1016/j.ijpe.2004.07.008

Zavertiaeva M.A., López-Iturriaga F.J., López-Iturriaga F.J. (2020) Networks of directors on Russian boards: The hidden part of the corporate governance iceberg. *Russian Management Journal*, 18(1), 29–50. https://doi.org/10.21638/spbu18.2020.102

Appendix 1. Technologies included in ICT profiles of Russian companies

Technology	Description
BPM	Business Process Management: improving organisations' performance and quality of work of by optimising business processes.
SaaS	Software as a Service: storing applications on remote servers with access via a web browser, eliminating the need to install them on user devices.
CRM	Customer Relationship Management: technologies for attracting and retaining clients, and improving customer relationships.
EDM	Electronic Document Management: creating, processing, storing and transmitting electronic documents in the organisation.
HRM	Human Resource Management: planning, hiring, training, performance management, employment termination.
WMS	Warehouse Management System: receiving, storing, and shipping goods.
LIS	Laboratory Information System: collection, processing and analysis of medical data.
TMS	Transportation Management System: route planning, cargo tracking, and vehicle management.
MES	Manufacturing Enterprise Solutions: planning, process monitoring, and product quality control.
PDM	Product Data Management: managing all product-related information.
PLM	Product Life Cycle Management: from concept to launch.
DC	Data Centres: processing data using servers and other computing equipment.
ITSM	IT Service Management: designing, creating, delivering, operating. and managing information technology services provided to clients.
SRS	Storage and Retrieval System: digitisation of electronic documents.
BI	Business Intelligence: collection, analysis, and transformation of data into information to help companies make better business decisions.
CPM	Corporate Performance Management: planning, budgeting, forecasting, and analysing financial and operational data to achieve the company's strategic goals.
FMS	Flexible Manufacturing System: managing equipment, materials, personnel, and production processes to optimise company operations.
IS	Information Security: protecting information from unauthorised access, leaks, damage, or destruction.
Cloud Computing	On-demand access to computing resources via the internet, such as servers, data storage, and applications, charging only for the use.
OSS/BSS	Operation Support System/Business Support System: integrated management of corporate telecommunication resources.
PaaS	Platform as a Service: providing access to internet platforms to users for developing, testing, and deploying applications without the need to manage infrastructure.
IaaS	Infrastructure as a Service: providing virtual computing resources over the internet, i.e. renting infrastructure such as virtual machines, data storage, and network resources as an alternative to purchasing and maintaining their own.
CMS	Content Management System: tools for creating, editing, and managing website content and access rights.
OLAP	Online Analytical Processing: collecting, processing, and analysing large volumes of data from various sources to support companies' strategic decision-making.
SCM	Supply Chain Management: managing the flow of goods and services from suppliers to end users, including inventory management, demand forecasting, order management, and logistics.
SRM	Supplier Relationship Management: solutions for strategic selection of suppliers, new product types from a number of possible alternatives, and implementing the entire procurement cycle, including electronic trading platforms.
PACS	Physical Access Control System: controlling access to buildings, premises, or information systems, including identification, authentication, and authorisation systems.
ERP	Enterprise Resource Planning: business process management system which allows companies to automate and improve management of personnel and resources, including finance, production, sales, and procurement.
VC	Video Conferencing systems, which allow users share video, audio, and text-based information in real time while being in different places.
VSS	Video Storage Systems: specialised applications for managing cameras, recording and playing back videos, analysing data, and warning about possible threats. Can be installed on system operators' computers or on special record storage and processing servers.
SCN	Satellite Communications and Navigation: communications between satellites and the Earth, establishing objects' location on the surface of the planet; navigation applications which use satellite systems' data to determine objects' precise coordinates.
PMS	Property Management System: managing time, budget, resources, objectives, and communication in the scope of a project.
VST	Vehicle Safety Technology: monitoring and managing vehicle safety by tracking their location, speed, driving direction, fuel consumption, engine state, and other parameters.
ATS	Automated Trading System: servers for managing cash registers; sales floor management systems; trading enterprise management systems; additional modules for trade management systems such as decision support, product layout automation, etc.
RBS	Remote Banking Service: providing access to bank accounts and services to clients via the internet.
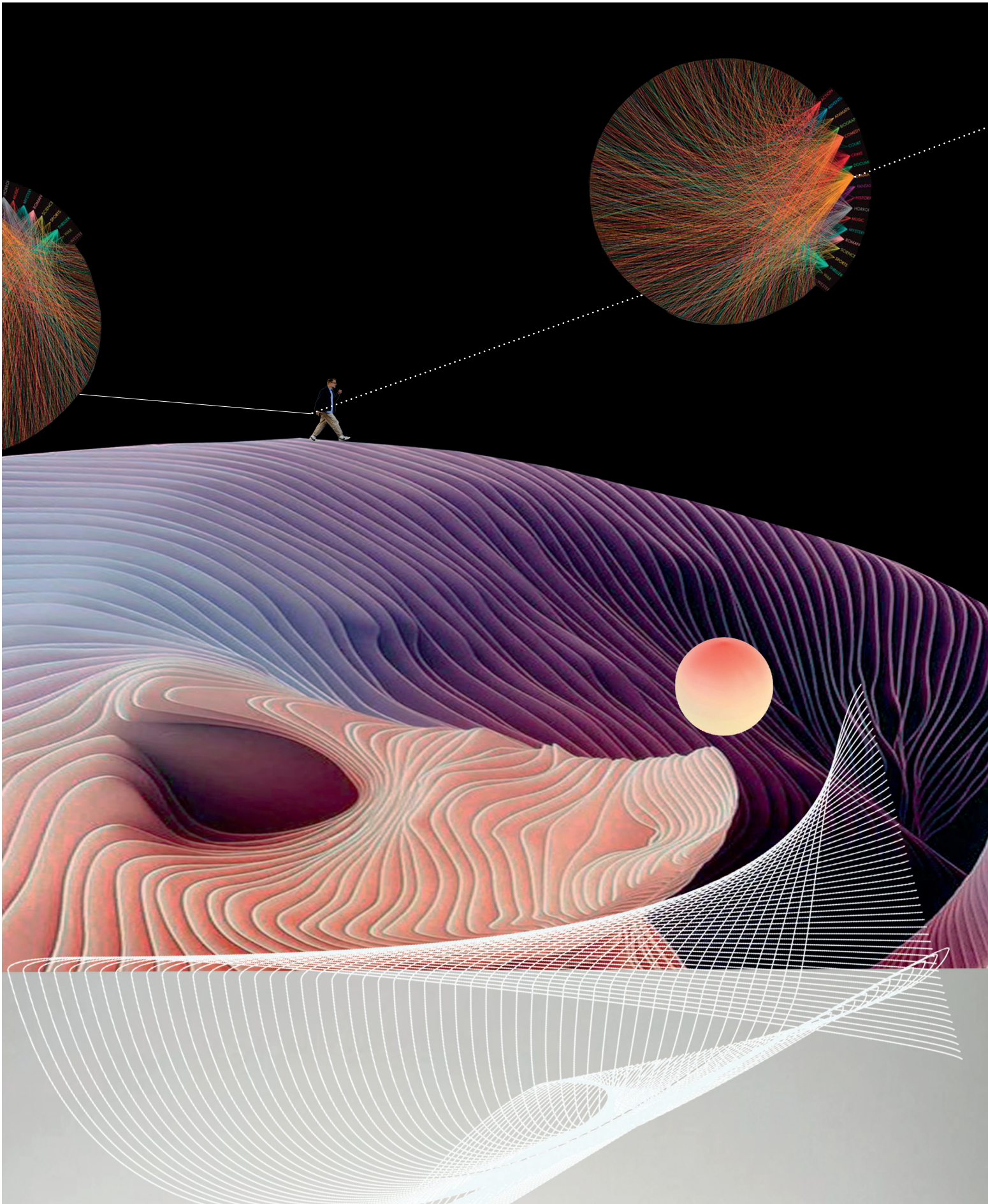
Foodtech as Part of the Circular Economy

Adrián Csordás

Lecturer, Faculty of Economics and Business, csordas.adrian19@gmail.com

University of Debrecen, 4032 Debrecen, Hungary

Abstract

Increasing food prices, intensifying competition, and even the need for sustainable operations lead players in the food sector to innovative strategies. Food Loss and Waste (FLW) is a major issue, the solution for which could significantly contribute not only to the achievement of Sustainable Development Goals (SDGs) but through novel approaches to the competitiveness and financial success of said actors. FLW studies are often related to production, while the retailers have not been broadly researched. Food upcycling has been emerging as an innovative solution, to transfer food loss into marketable food products. The current study analyzes the surplus-based upcycled food products' consumer acceptance and the competitive advantages that could be realized by the exploitation of this innovative approach. Following the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) guidelines, some of the essential product features could be observed based on academic publications.

The upcycled food is not well-known. Individuals who are environmentally conscious most support this type of product. However, the low level of processing was seen as a desirable feature for everyone. Due to the low level of processing, technophobia should not hamper, but rather support the spread and use of surplus-based products. Similar to conventional food, taste, sensory appeal, and price are those characteristics that can influence consumers' decision-making. Without a significant increase in marketing expenditures, innovative retailers can influence potential customer engagement through comprehensive and educational advertising. Offline presentations and trials are consistently more persuasive in involving customers, but the significance of online information sharing is equally important. These results imply that innovative businesses, by selling upcycled food, could realize competitive advantages from multiple sources while contributing to the SDGs.

Introduction

The food sector is a dynamic and competitive industry, where retailers play a crucial role in shaping consumer choices and influencing the overall food system. These actors face a multitude of challenges and opportunities in navigating the evolving landscape of food production, consumption, and waste. Retailers must constantly differentiate themselves to attract and retain customers. Pricing is one of the decisive factors where they can compete. Due to this reason, food companies strive to find ways to lower their costs and pass those savings on to consumers. The other relevant area of competition is product assortment, where product offering has to fit the needs of the customers, but the economic aspects of the operation have to play a crucial role, too. The innovative retailers who can collectively consider and solve these issues should gain competitive advantages. All these challenges are embodied in the food waste generated by retailers. It provides an unexploited potential for the utilization of surplus. According to the Food and Agriculture Organization of the United Nations (FAO) (2011), approximately one-third of all food produced is lost or wasted globally. The distribution of it along the value chain varies considerably, but a relevant share of FLW is created at the retail level (Luo et al., 2022; Goodman-Smith et al., 2020). Particularly inadequate storage, incorrect forecasting, and overstocking practices contribute to the high loss of retailers (Herzberg et al., 2022; Riesenegger, Hübner, 2022; de Moraes et al., 2020). To mitigate these, the products close to their expiration date are often proffered with high discounts (Wu, Honhon, 2023; Tsalis et al., 2021). However, after this time the unmarketable products do not generate significant income, since these are often donated, composted, or sold to companies that recycle or upcycle them (Lowrey et al., 2023; Nenciu et al., 2022; Huang et al., 2021). The innovative players in production have discovered the market value of the byproducts. Upcycling involves transforming food loss into new and valuable products, diverting it from landfills, and reducing environmental impact (Punia Bangar et al., 2024; Mirosa, Bremer, 2023). This creative approach not only reduces food loss but also generates new revenue streams for businesses (May, Guenther, 2020) while contributing to environmental and social responsibility (Horoś, Ruppenthal, 2021; Jeswani et al., 2021).

Food upcycling encompasses a wide range of innovative solutions, which are mostly based on byproducts. Although the difference is significant between products made from byproducts and surplus food, these are rarely emphasized. Surplus food refers to food that is produced (or harvested) over what is required or demanded (Papargyropoulou et al., 2014). Meanwhile, a byproduct is a secondary product or substance that is produced during the manufacture or processing of another primary product (Raţu et al., 2023). The first was made for human consumption, but the second could be used for the same purpose only after processing (Damiani et al., 2021; Alao et al., 2017). The definition of upcycled food also often confuses the "raw material" used in the process (Thorsen et al., 2022). Beyond the theoretical issues, the differences in the management of creating edible products from these various raw materials are much more significant. While in one case a predictable amount of a given raw material is available, in another neither the product nor its amount is foreseeable. This phenomenon could make it complicated for innovative retailers to plan. However, it could be worth addressing this, since lately consumers face higher food prices worldwide (due to the consequences of inflation caused by the pandemic and war) which lead many of them to economize (Abay et al., 2023; Fan et al., 2023), and simultaneously one must consider the growing attention to and importance of eco-friendliness, which could foster demand for upcycled food (Chanda et al., 2023; Kim, Lee, 2023; Sharma et al., 2023). The current work aims to study the niche of surplus-based upcycled food products through the consumers' acceptance. Based on the provided comprehensive overview, this work highlights the potential benefits of this innovative approach's early adoption in the retail.

Material and Methods

A systematic literature review offers a structured approach to evaluating the available evidence related to a specific research question. This method encompasses the identification, evaluation, and analysis of relevant studies filtered by specific search criteria published in high-quality journals (Mishra, Mishra, 2023). To conduct comprehensive research the Preferred Reporting Items for Systematic Reviews and Meta-Analyses for Protocols (PRISMA) guidelines were followed, which were originally used for healthcare-related studies (Page et al., 2021). To achieve an extensive base the academic databases of Scopus, Web of Science, and Science Direct were used. Since the current work aimed to identify and synthesize the existing evidence on the acceptance of upcycled food, the used keywords were the following: acceptance, food, upcycling, and upcycled. The application of "and", and "or" operators provided a more specific search query. The records of the databases had to contain these terms in the title, abstract, or keywords. Only scientific articles written in English were evaluated, which have been recorded until December 26, 2023. A total of 682 relevant articles were identified. These works were managed by Rayyan, which is an online free-to-use platform to facilitate systematic literature reviews.[1] The in-

---

[1] https://www.rayyan.ai/, accessed 18.01.2024.

cluded works had to be based on primary data, and the definition of upcycled food applied in the given study was strictly reviewed. Given that the term "upcycled food" means different products in many cases (Spratt et al., 2021). The definitions used by the identified studies in this research were analyzed one by one. The number of articles that examined only the acceptance of food not produced using byproducts was rather low. Therefore, those studies whose definition did not exclusively focus on surplus in their definition were also analyzed. Unfortunately, surplus food is often considered as food waste (FAO, 2015), and due to this theoretical issue, this expression could not be added to the search criteria. To extend the number of the studied works, the references of the publications and even materials outside the academic sphere (grey literature) were checked. However, there was no suitable material to be added. This phenomenon may also support the under-representation of the given topic. Figure 1 presents the structure of the applied method.

After the selected articles were uploaded to Rayyan, the duplicates and irrelevant studies were identified. After this round, 552 articles remained as the basis of the systematic literature review. The initial screening was based on the abstracts which resulted in the exclusion of 174 articles. In the next section, the remaining 378 studies were analyzed to identify the various fields within the domain of upcycled food consumer acceptance. The popularity of upcycling in general has been rising as a significant method that supports the realization of various SDGs. Due to this issue, a wide range of less relevant studies could be found within the current database as well. As seen in Figure 2 a high share of works studied "plastic" in 2023. The relevance of this topic is probably due to the significant increase in research on which food (food waste) can be used to replace plastic food packaging with degradable or edible covers (Bhargava et al., 2020; Dilkes-Hoffman et al., 2018). The distribution of the topics not related to the current research was as follows; battery: 17, building: 77, electronic waste: 21, fashion: 34, plastic: 73, theory: 84, soil: 6, and wastewater: 21. After a thorough examination of available research only five relevant academic publications were left.

The "building" related articles also presented a high share. However, this approach of upcycling does not truly offer a sustainable solution to food waste. Since the use of construction materials regularly does not return to nature as organic components (Zhang et al., 2022; Barbu et al., 2021). The share of works focused on "wastewater" was also substantial. This field could have a high impact in the near future on the food industry through the increased agricultural productivity (Lee et al., 2022; Roman, Brennan, 2021).
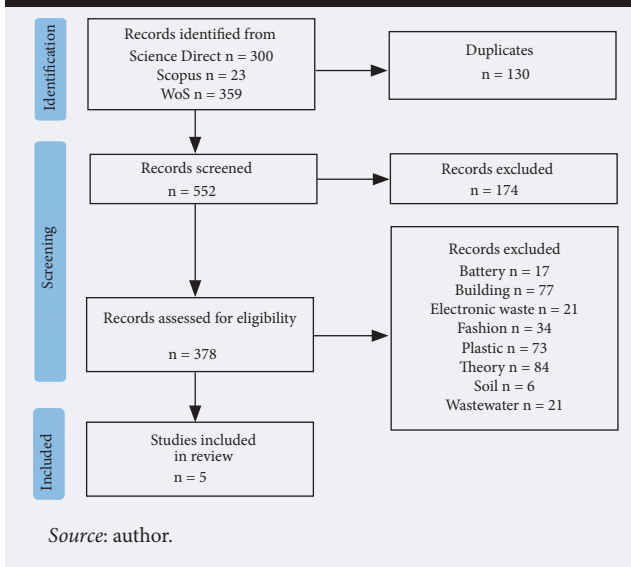
Results

Related Reviews

An analysis of the review articles was carried out to gain insight into the existing body of knowledge. To achieve this, the same PRISMA method was used that provided the basis for the study, but this time only the relevant articles were involved. From the fifty-three reviews, only four could be considered relevant for the current study. Their main findings are presented in Table 1. The published studies revealed major differences between the used definitions. The various approaches differed regarding the source of the upcycled food. The broad approach defines the raw material as an ingredient that otherwise would not be used for human consumption (Moshtaghian et al., 2021). A more specific approach points out that these materials are typically discarded near the source, and are often called co-streams or byproducts (Bhatt et al., 2020). While only the most widely used approach involves surplus as a possible source of upcycled food (Thorsen et al., 2022). These substantial variances in the definitions became clear during the analysis of the research articles.
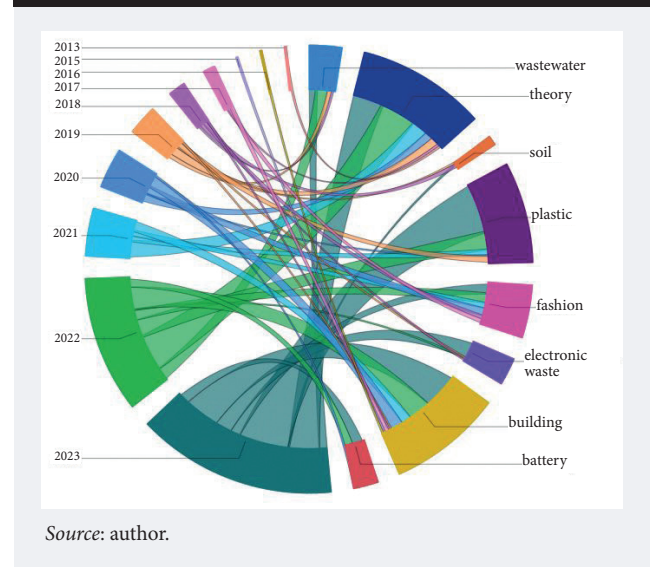
Academic Papers

The study of Jamaludin et al., (2022) delves into the issue of food waste in Malaysia. The data was collected in an urban area of Kuala Lumpur between October and November 2021, where 147 participants answered a semi-structured questionnaire. The authors also conducted a pilot test, to verify the clarity and validity of the questions. The respondents had to choose between two models based on their preferences. The first option suggested that the produced food would be consumed by the households and the potential leftovers would be used as landfills, so increasing the amount of methane and carbon dioxide gases, which is disadvantageous for climate change. In the other case, the food will be consumed, and the potential leftovers will be used to provide higher-quality products by reprocessing. The overwhelming part of the surveyed chose the second – circular economy – model. The ten percent of the respondents who preferred the first option were men with low income and education levels. Questions were asked related to the taste of the upcycled products as well. All in all, less than twenty percent found that the upcycled food had a suboptimal or bad taste. This high openness paired with a willingness to pay since seven out of ten respondents would be ready to pay a given amount of money weekly for a driver to collect the food waste from their homes. Nearly six out of ten would be ready to pay even more for it, in addition, the less open people would be ready to pay a lower amount for this service too.

Figure 1. **Process of the Systematic Literature Review**

Source: author.

Figure 2. **The topics and their publication year excluded from the current database**

Source: author.

Hellali and Korai, (2023) studied the acceptance of upcycled food through the innovation behind these products. The data source was provided by Dynata's consumer panel. It created 1014 participants' answers, which accurately represented the demographics of Quebec. Before the run of data collection pilot test was done, and even CERUL ethical approval was received. The authors created three questionnaires through SurveyMonkey, which were mostly based on a 5-point Likert scale. The surveys presented upcycled food from various points of innovation. The first level was the incremental innovation. This approach focuses on meeting particular consumer requirements or enhancing existing product features. In the given study, beer made from wasted bread embodied this stage. The second level was so-called disruptive innovation, which brings new methods, technologies, or business models that significantly change how a product or service is perceived, delivered, or used. This can be exemplified by vegan mayonnaise made from aquafaba (chickpea water). The most significant changes created for the market and consumer were surveyed through radical innovation. This stage can be characterized by transformations that profoundly influence the product, give rise to completely new and pioneering concepts, and surpass conventional boundaries by introducing revolutionary ideas. An example of this could be 3D-printed snacks made from dehydrated dough. The surveyed were randomly appointed to one of the questionnaires, where each survey included three examples to promote understanding. Confirmatory factor analysis was applied to validate the reliability, convergence, and discrimination properties of the latent variables (i.e., Attitude, Behavioral Intention, Ecological Consciousness, Food Neopho-

bia, Perceived Usefulness, and Risk Aversion). Except for "Risk Aversion," all items related to the latent variables' factor loadings were greater than 0.5, but it was not removed. As this finding contributed to the scale's validity, it ensured further evidence of the model's convergent validity. The created model's ability to represent the data was supported by various fit measures like RMSEA, CFI, or TLI. The statistical tests revealed a clear connection between favorable attitudes toward upcycled foods and the willingness to consume them. Through these measures, the authors also stated, that the belief that food products from the circular economy are beneficial positively affects consumer attitudes toward upcycled food. Environmental awareness has a positive effect on the perception of the usefulness of food technologies that incorporate waste into edible products. Food neophobia, risk aversion, and the degree of innovation applied by these technologies have a negative influence on perceived usefulness. The higher innovation in the food product is combined with the lower perceived usefulness of the innovation. This is explained by the sensory appeal and emotional response of disgust associated with upcycled food technology. Regarding gender, women were more likely to adopt upcycling technologies than men. However, age did not have a statistically significant effect on the likelihood of adopting these technologies in the study.

The research of Moshtaghian et al. (2023) aimed to analyze consumer preferences for the nutritional, environmental, and food safety aspects of upcycled food. The data for the study was collected by questionnaire. The authors focused on sociodemographic data, attitudes, and factors motivating up-

Table 1. **Studies Reviewing the Academic Literature on the Acceptance of Upcycled Food**	
Issues Reviewed (Source)	**Key Findings**
Stages of consumer behavior in the transition to circular food systems	The transition of the consumers could be divided into tree stages; Linear: It can indirectly foster circularity by promoting secondary environmental or social advantages. Transitioning: This is characterized by the coexistence of traditional patterns and emerging circular practices. Circular: It is a lifestyle choice driven by consumer engagement.
The carbon footprint labels' effect on consumers (Rondoni, Grasso, 2021)	Women who are more environmentally conscious and have higher levels of education and income are more likely to support carbon footprint labels.
Which factors affect the acceptance of byproduct-based food? (Aschemann-Witzel, Stangherlin, 2021)	Product attributes, situational factors, and personal characteristics influence the acceptance of byproduct-based food. Promoting environmental awareness and highlighting the environmental benefits can further enhance it.
Challenges for upcycled food (Moshtaghian et al., 2021)	Strive to define the meaning of upcycled food, its position within food waste management strategies, and its consumers.
Source: author.	

cycled food choices. The questions concentrated on concerns related to the environmental impact of food waste, previous experiences with upcycled food, intention for its consumption, relevance of its value-added feature in addition to preferences for conventional food over upcycled food. The questions were grouped into the following three sections: nutritional, environmental, and food safety characteristics. A 5-point Likert scale was mostly used for data collection. Not only was a definition provided in the survey (those food products that are made from ingredients that would not be consumed or would be wasted) but some examples were given as well. The answers were recorded through the SU-NET platform on the University of Boras website. The English and Swedish questionnaires were filled out by 681 Swedish residents aged 18 or older, residing in Sweden between September 2021 and December 2021. The demographical analysis showed that women were the majority in all age groups. Additionally, the share of elderly individuals living independently in small households without children was higher than that of other age groups. The statistical tests revealed that the respondents between 18–39 years have somewhat higher concerns related to the environmental impact of food waste compared to the other age groups. All the studied clusters were open to the consumption of upcycle food, and approximately half of the surveyed people had already eaten it. However, the other half of the participants were uncertain whether they had ever consumed it. In all three age groups (18–39, 40–64, 65+), one out of ten respondents preferred conventional foods over upcycled food, and the same share considered the value-added feature of these products relevant. The nutritional characteristics of the upcycled product were the less important for all the groups. The nutritious and the minimally processed features were the most relevant. None of the clusters considered low energy and low-fat content as significant nutritional characteristics of upcycled food. The younger participants had fewer problems with processed/minimally processed products than middle-aged and elderly participants. This group also considered the nutritious features less relevant, nor did they focus on the vitamin and mineral content of the upcycled products as the oldest participants did. All the participants found the contribution of upcycled products to a lower level of food waste the most relevant. In second place, the youngest participants ranked green production. Meanwhile the middle-aged group positioned green packaging in the second place. None of the surveyed groups were particularly interested in the location of production. Nevertheless, local production was more relevant for the oldest respondents than the younger ones. The younger respondents worried less compared to other groups about green packaging. The authors analyzed the food safety-related characteristics of upcycled products as well. All respondents named the lack of contaminants and harmful substances of the utmost importance. The oldest and middle-aged paid more attention to the lack of GMOs, hormones, additives, and chemicals than the youngest group. Regarding the sociodemographic attributes, the first Generalized Linear Model – adjusted for gender – showed up positive connection between the age and the importance score of all nutritional features. The second Generalized Linear Model– adjusted for education, employment status, and income – did not reveal the same linkage in the case of fiber content, high-protein, and nutritious features. Related to the environmental characteristics, none of the models showed a significant relationship between the age and the importance of green production in addition to packaging. The first model revealed a positive relation between age and local production, but the second model did not. Even though there was no connection between the relevance of food waste reduction and age in the case of the first model, in the second model a negative association was found. Regarding the nutritional characteristics, all food safety characteristics' scores showed a positive relationship with the age in the first model, while the absence of poison and contamination did not reflect that in the second model.

The study of Goodman-Smith et al. (2023) analyzed how consumers in New Zealand respond to upcycled craft beer and how could it be effectively promoted. For data collection, the researchers together with the Citizen Collective developed a survey, which was tested (pilot) with customers. Using a non-random sampling method and an exploratory research approach, the finalized questionnaires were used in-store in February 2021 and online in March 2021. During the in-store data collection (which had ethics approval from the University of Otago Ethics Committee) a dedicated corner was created for this purpose, where the customers were informed about the product's origins and the manufacturing process. They learned it was made from surplus bread and had a chance to try it. After this, the was survey completed, which focused on their preferences for craft beer, their knowledge and perceptions related to upcycled food, their opinions on upcycled craft beer versus conventional craft beer, and factors that would influence their future purchases of upcycled food. Through this method, sixty-five answers were collected. The online survey was run on the platform "Yabble" according to the code of ethics for the Research Association of New Zealand. The craft beer consumers of PAK'nSAVE and New World panels were called upon to participate. In that way, three hundred answers were collected. The analysis of the answers was based on the comparison of the two samples. Regardless of where the respondents were involved in the study, taste, price, and country of origin were named as the most important aspect in selecting craft beer. The offline respondents paid more attention to company ethics, sustainability, and taste than the online ones. The z-test revealed that a higher share of in-store participants had prior knowledge of upcycled foods compared to the online ones. The three most significant benefits of upcycled food in both of the samples were sustainability in addition to the reduction of food waste and a lower carbon footprint. However, statistically, more offline consumers found the upcycled beer sustainable, as it decreases one's carbon footprint while increasing social status. In contrast, the people surveyed online were more likely to pair upcycled beer with nutritional benefits and higher earnings for producers than the in-store customers. A higher share of respondents who were surveyed offline expressed concerns related to the taste of upcycled food compared to those who answered the survey online. Based on a statistical test, a higher proportion of offline participants expressed concerns about the cost and quality of upcycled food. Meanwhile a higher share of online participants believed there were no negative aspects of upcycled food. In both of the groups only a small minority worried about food safety issues related to these products. Eight out of ten offline participants found

the upcycled beer a little more or a lot more appealing than conventional beers. However, only five out of ten online customers thought the same. The statistical test proved a significant difference between the two groups. Nearly a two times higher share of online respondents found the upcycled beer less appealing than conventional beer, compared to the offline participants. No offline participants found the upcycled beer less appealing than conventional beer. According to the offline respondents, labeling could help the most for spreading word about the product. In contrast, the price was identified as the most significant factor for promotion by the online respondents. These people also identified third-party endorsement, a dedicated upcycled area, and price as crucial promotional tools.

The work of Moshtaghian et al. (2024) explored the driving forces behind consumer preferences for upcycled food and studied the relationship between the motivations and hesitancy surrounding upcycled food consumption. For data collection a questionnaire to uncover factors that could influence upcycled food choices, furthermore, sociodemographic questions were posed as well. The respondents answered mostly on a 5-point Likert scale and were informed about the definition of upcycled food. The current work defined it as products made from ingredients that would have ordinarily been discarded or wasted. These products are crafted from imperfect or damaged goods, food scraps, and byproducts from the food preparation process. The online survey was accessible between September 1 and December 1, 2021. During this period 682 Swedish respondents filled it out. Almost eight out of ten participants showed a willingness to consume upcycled food. The participants were classified (inclined or hesitant groups) based on their answers. In both of the groups, the average age of participants was 48 years, but a few more women could be found in the first group. The inclined group also had a higher percentage of full-time employed individuals and higher household incomes. The hesitant group meanwhile had a higher proportion of postgraduate-educated participants living alone. The following seven factors were identified by the explanatory factor analyses that influence the consumption of upcycled food; natural content, ethical concerns, healthiness, familiarity, sensory appeal, price, and impression. The hesitant respondents placed the highest importance on good taste, followed by chemical-free certification and natural ingredients. In contrast, the more open participants emphasized the contribution to food waste reduction, animal welfare, and chemical-free certifications. The groups did not differ significantly in their mean importance scores for items related to natural content. However, a significant difference was measured in the mean importance scores for items re-

lated to familiarity, sensory appeal, and impression. Related to the ethical concerns, there was a significant difference in the average importance ratings of most food choice factors between the studied types of respondents. A statistically significant difference was found in the mean importance ratings of low fat, low energy, and high protein content regarding the healthiness aspects among the various consumers. Both groups' consumers looked at ethical concerns as the most crucial factor when choosing upcycled food. Natural content and sensory appeal followed in importance. However, impression did not play a relevant role at all in any of the groups. The comparative analysis highlighted that, except for natural content, the average importance scores of all other factors significantly differed between the hesitant and inclined consumers. Those participants who were ready to consume upcycled food more frequently raised ethical concerns related to food waste reduction. Those respondents who considered ethical concerns a significant factor in their decision were 60% less likely to hesitate to consume upcycled food. However, the participants who prioritized healthiness and sensory appeal in their decision were significantly more likely to be hesitant, compared to those who did not prefer these features. In addition, those who named the appearance as a major feature were 2.4 times more likely to be hesitant, than those who did not focus on it.

Discussion

The presented scientific articles studied the same phenomenon from various perspectives, which made it challenging to summarize the diverse variables and their effect on the acceptance of upcycled food products. The analyzed variables also aligned with the focus of the given study, but some common tendencies even could be seen. The consumers' knowledge regarding upcycling products is not so vast. According to the reviewed works, people who are into eco-friendly consumption seem to be open to this food. Regarding the nutrient content, the members of older generations tend to have more expectations than the younger ones. However, this feature should be less relevant, as a higher level of processing is needed to produce a value-added product (which is one of the attributes of byproduct-based food). In contrast, the low level of processing appeared to be a desired feature of the upcycled products. The taste, price, and level of processing seem to be general issues, which strongly can influence the decision-making of consumers. Considering that the acceptance of various food products was broadly studied, based on the last fifty years of scientific publications recorded by the Web of Science, several major attributes could be underlined related to the current study. Figure 3, created from over 11,000

studies' abstracts, divides the relevant features into two significantly different clusters.

The red words are product-related terms that could be evaluated when (similar) goods are compared. The green words are connected to consumers' attitudes, which could influence whether the red factors are relevant at all. When considering consumer attitudes, high demand for information is one of the decisive factors. The other key aspect within the same cluster is linked to production. Regarding the upcycled food products, informing the respondents about upcycled food (by for example, providing a definition, an example, or trial) was crucial in the majority of the studies, as this approach is emerging and not part of general public knowledge. The lack of information could be handled by directed advertising and in-store presentations. The in-person format with trials tends to be more convincing in engaging customers, but the role of online information sharing is also crucial. Reaching the widest possible audience can be costly, but compared to regular marketing expenditures, the advertising of upcycled products should not be a significant cost (Lehn, Schmidt, 2022). However, in the second case regarding production, technophobia is much more difficult to overcome. Food technophobia is a phenomenon that describes consumers' rejection or resistance to novel food innovations (Wendt, Weinrich, 2023). Retailers have to take it seriously because it is one of the most significant limitations of a product range's expansion (Siddiqui et al., 2022). Considering the customer fears, minimal processing (e.g., drying, grinding, cooking) and a flood of information could open up new avenues for surplus-based upcycled products. Well-positioned items could not only mitigate the financial loss in the short term, but could provide various benefits from multiple sources in the long term as presented in Figure 4.

From a business perspective, the demonstration of a firm commitment to sustainability can appeal to environmentally conscious consumers and reflect creativity and an innovative mindset (Ishaq, Di Maria, 2020; Zameer et al., 2020; Loučanová et al., 2021). These associations could be incorporated into the retailer's brand. Although the supply of surplus food is unpredictable, this still could be beneficial. Through the various unsold products, everyday unique sustainable food options could be proffered, which improves companies' product diversification (Araujo et al., 2021; Ojha et al., 2020). Upcycling could also reduce financial losses, while increasing revenue through the higher sales (Paraskevopoulou et al., 2022; May, Guenther, 2020). In addition, the nonfinancial report could be improved with proven good practices, which could garner interest from green investors (Jaouhari et al., 2023; Ng, 2021). From an environmental perspective, by up-

Figure 3. **Information and Production, the Most Relevant Factors for Consumer Acceptance**

Source: author.

Figure 4. **Benefits of Upcycling's Early Adoption**
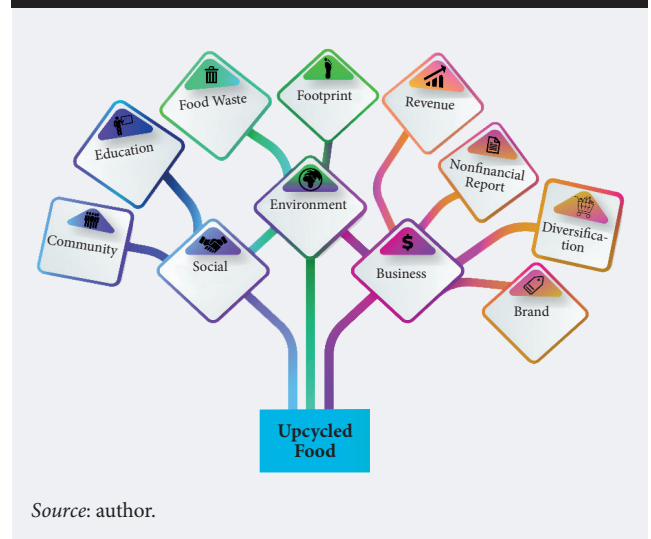

Source: author.
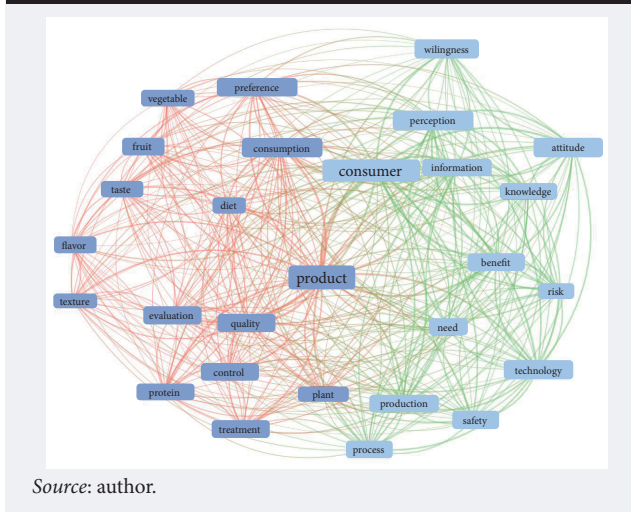
cycling, the amount of food waste could be significantly reduced (Tchonkouang et al., 2023). This also mitigates the emission of greenhouse gases that are produced during the decomposition of food waste (Jain, Gualandris, 2023). Upcycling also has social benefits. The sustainable lifestyle and values could bring people together and encourage consumers to adopt these practices at home. By promoting upcycling, children can also develop skills in cooking and nutrition (Coppola et al., 2021; Rondeau et al., 2020).

Conclusions

A constantly changing environment, new consumer demands, and the highly competitive nature of the market are some of the difficulties faced by retailers. Innovation is one of the opportunities that could help businesses in the food sector succeed. The enormous amount of Food Loss and Waste (FLW) generated by the retailers provides a hidden opportunity for the realization of a competitive advantage. However, according to the reviewed studies, until now this issue has only been studied at the production level. Upcycling is an innovative method to handle emergent challenges andsuch products are currently not well-known. Despite the lack of consumer knowledge, technophobia has not appeared in the reviewed articles, which propose a generally low level of upcycled food rejection. The decisive product features for upcycled food are similar to those of conventional products, which suppose the existence of a niche. The sales of these upcycled products could create a new sustainable alternative food category for retailers. However, this innovative solution needs extensive marketing campaigns to spread public knowledge about these products. Through in-store trials, consumer engagement could be quickly improved and the benefits of such innovations could be realized even in the short term. These advantages would furthermore improve contributions to the Sustainable Development Goals (SDGs). By reducing Food Loss and Waste, more food would be available, while resources such as land, water, and energy would be conserved. The lower level of FLW could help to protect forests and other natural habitats, in addition to mitigating climate change. Considering the growing eco-friendliness and price sensitivity on the consumer side, the positive associations with sustainable operating retailers could be built into the pioneers' brands. Furthermore, through the contribution of social values, the innovative retailers may be preferred by families as well. However, due to the hardly predictable nature of consumer demand and surplus, a permanent lack of upcycled products could disappoint potential clients. The retailers also have to the physical and human resource needs, by constantly developing new food products and recipes, and align those new products with the local regulations. Despite these difficulties, for smaller (e.g., family-owned) retailers, upcycling is certainly a great opportunity to reduce losses and build their brand. For larger (national/international) chains, the standardization of upcycling could cause difficulties. These challenges should be analyzed in future studies.

References

Abay K.A., Breisinger C., Glauber J., Kurdi S., Laborde D., Siddig K. (2023) The Russia-Ukraine war: Implications for global and regional food security and potential policy responses. *Global Food Security*, 36, 100675. https://doi.org/10.1016/j.gfs.2023.100675

Alao B., Falowo A., Chulayo A., Muchenje V. (2017) The Potential of Animal By-Products in Food Systems: Production, Prospects and Challenges. *Sustainability*, 9(7), 1089, https://doi.org/10.3390/su9071089

Araujo J., Sica P., Costa C., Márquez M.C. (2021) Enzymatic Hydrolysis of Fish Waste as an Alternative to Produce High Value-Added Products. *Waste and Biomass Valorization*, 12(2), 847–855. https://doi.org/10.1007/s12649-020-01029-x

Aschemann-Witzel J., Stangherlin I.D.C. (2021) Upcycled by-product use in agri-food systems from a consumer perspective: A review of what we know, and what is missing. *Technological Forecasting and Social Change*, 168, 120749. https://doi.org/10.1016/j.techfore.2021.120749

Barbu M.C., Montecuccoli Z., Förg J., Barbeck U., Klímek P., Petutschnigg A., Tudor E.M. (2021) Potential of Brewer's Spent Grain as a Potential Replacement of Wood in pMDI, UF or MUF Bonded Particleboard. *Polymers*, 13(3), 319. https://doi.org/10.3390/polym13030319

Bhargava N., Sharanagat V.S., Mor R.S., Kumar K. (2020) Active and intelligent biodegradable packaging films using food and food waste-derived bioactive compounds: A review. *Trends in Food Science & Technology*, 105, 385–401. https://doi.org/10.1016/j.tifs.2020.09.015

Bhatt S., Ye H., Deutsch J., Ayaz H., Suri R. (2020) Consumers' willingness to pay for upcycled foods. *Food Quality and Preference*, 86, 104035. https://doi.org/10.1016/j.foodqual.2020.104035

do Canto N.R., Grunert K.G., De Barcellos M.D. (2021) Circular Food Behaviors: A Literature Review. *Sustainability*, 13(4), 1872. https://doi.org/10.3390/su13041872

Chanda R.C., Isa S.M., Ahmed T. (2023) Factors influencing customers' green purchasing intention: evidence from developing country. *Journal of Science and Technology Policy Management* (ahead-of-print). https://doi.org/10.1108/JSTPM-03-2022-0044

Coppola C., Vollero A., Siano A. (2021) Consumer upcycling as emancipated self-production: Understanding motivations and identifying upcycler types. *Journal of Cleaner Production*, 285, 124812. https://doi.org/10.1016/j.jclepro.2020.124812

Damiani M., Pastorello T., Carlesso A., Tesser S., Semenzin E. (2021) Quantifying environmental implications of surplus food redistribution to reduce food waste. *Journal of Cleaner Production,* 289, 125813. https://doi.org/10.1016/j.jclepro.2021.125813

Dilkes-Hoffman L.S., Lane J.L., Grant T., Pratt S., Lant P.A., Laycock B. (2018) Environmental impact of biodegradable food packaging when considering food waste. *Journal of Cleaner Production,* 180, 325–334. https://doi.org/10.1016/j.jclepro.2018.01.169

Fan X., Wang X., Xu Z., Skare M. (2023) Food price inflation convergence: An international study from 2000–2020. *British Food Journal,* 125(3), 794–809. https://doi.org/10.1108/BFJ-12-2021-1314

FAO (2011) *Global Food Losses and Food Waste – Extent, Causes and Prevention*, Rome: FAO.

FAO (2015) *Global Initiative on Food Loss and Waste Reduction — What is Food,* Rome: FAO.

Goodman-Smith F., Bhatt S., Grasso S., Deutsch J., Mirosa M. (2023) Consumer acceptance of upcycled craft beer: A New Zealand case study. *Frontiers in Nutrition,* 10, 1235137. https://doi.org/10.3389/fnut.2023.1235137

Goodman-Smith F., Mirosa M., Skeaff S. (2020) A mixed-methods study of retail food waste in New Zealand. *Food Policy,* 92, 101845. https://doi.org/10.1016/j.foodpol.2020.101845

Hellali W., Korai B. (2023) Understanding consumer's acceptability of the technology behind upcycled foods: An application of the technology acceptance model. *Food Quality and Preference,* 110, 104943. https://doi.org/10.1016/j.foodqual.2023.104943

Herzberg R., Schmidt T., Keck M. (2022) Market power and food loss at the producer-retailer interface of fruit and vegetable supply chains in Germany. *Sustainability Science*, 17(6), 2253–2267. https://doi.org/10.1007/s11625-021-01083-x

Horoś I.K., Ruppenthal T. (2021) Avoidance of Food Waste from a Grocery Retail Store Owner's Perspective. *Sustainability,* 13(2), 550. https://doi.org/10.3390/su13020550

Huang I.Y., Manning L., James K.L., Grigoriadis V., Millington A., Wood V., Ward S. (2021) Food waste management: A review of retailers' business practices and their implications for sustainable value. *Journal of Cleaner Production,* 285, 125484. https://doi.org/10.1016/j.jclepro.2020.125484

Ishaq M.I., Di Maria E. (2020) Sustainability countenance in brand equity: A critical review and future research directions. *Journal of Brand Management,* 27(1), 15–34. https://doi.org/10.1057/s41262-019-00167-5

Jain S., Gualandris J. (2023) When does upcycling mitigate climate change? The case of wet spent grains and fruit and vegetable residues in Canada. *Journal of Industrial Ecology*, 27(2), 522–534. https://doi.org/10.1111/jiec.13373

Jamaludin H., Elmaky H.S.E., Sulaiman S. (2022) The future of food waste: Application of circular economy. *Energy Nexus,* 7, 100098. https://doi.org/10.1016/j.nexus.2022.100098

Jaouhari Y., Travaglia F., Giovannelli L., Picco A., Oz E., Oz F., Bordiga M. (2023) From Industrial Food Waste to Bioactive Ingredients:A Review on the Sustainable Management and Transformation of Plant-Derived Food Waste. *Foods*, 12(11), 2183. https://doi.org/10.3390/foods12112183

Jeswani H.K., Figueroa-Torres G., Azapagic A. (2021) The extent of food waste generation in the UK and its environmental impacts. *Sustainable Production and Consumption*, 26, 532–547. https://doi.org/10.1016/j.spc.2020.12.021

Kim N., Lee K. (2023) Environmental Consciousness, Purchase Intention, and Actual Purchase Behavior of Eco-Friendly Products: The Moderating Impact of Situational Context. *International Journal of Environmental Research and Public Health*, 20(7), 5312. https://doi.org/10.3390/ijerph20075312

Lee J.I., Oh J.S., Yoo S.C., Jho E.H., Lee C.G., Park S.J. (2022) Removal of phosphorus from water using calcium-rich organic waste and its potential as a fertilizer for rice growth. *Journal of Environmental Chemical Engineering*, 10(2), 107367. https://doi.org/10.1016/j.jece.2022.107367

Lehn F., Schmidt T. (2022) Sustainability Assessment of Food-Waste-Reduction Measures by Converting Surplus Food into Processed Food Products for Human Consumption. *Sustainability*, 15(1), 635. https://doi.org/10.3390/su15010635

Loučanová E., Šupín M., Čorejová T., Repková-Štofková K., Šupínová M., Štofková Z., Olšiaková M. (2021) Sustainability and Branding: An Integrated Perspective of Eco-innovation and Brand. *Sustainability*, 13(2), 732. https://doi.org/10.3390/su13020732

Lowrey J.D., Richards T.J., Hamilton S.F. (2023) Food Donations, Retail Operations, and Retail Pricing. *Manufacturing & Service Operations Management*, 25(2), 792–810. https://doi.org/10.1287/msom.2022.1185

Luo N., Olsen T., Liu Y., Zhang A. (2022) Reducing food loss and waste in supply chain operations. *Transportation Research Part E: Logistics and Transportation Review*, 162, 102730. https://doi.org/10.1016/j.tre.2022.102730

May N., Guenther E. (2020) Shared benefit by Material Flow Cost Accounting in the food supply chain – The case of berry pomace as upcycled by-product of a black currant juice production. *Journal of Cleaner Production*, 245, 118946. https://doi.org/10.1016/j.jclepro.2019.118946

Mirosa M., Bremer P. (2023) Understanding New Foods: Upcycling. In: *Sustainable Food Innovation* (Sustainable Development Goals Series) (ed. L. Serventi), Cham: Springer. https://doi.org/10.1007/978-3-031-12358-0_11

Mishra V., Mishra M.P. (2023) PRISMA for Review of Management Literature – Method, Merits, and Limitations – An Academic Review. In: *Advancing Methodologies of Conducting Literature Review in Management Domain* (vol. 2) (eds. S. Rana, J. Singh, S. Kathuria), Leeds: Emerald, pp. 125–136. https://doi.org/10.1108/S2754-586520230000002007

de Moraes C.C., de Oliveira Costa F.H., Roberta Pereira C., da Silva A.L., Delai I. (2020) Retail food waste: Mapping causes and reduction practices. *Journal of Cleaner Production*, 256, 120124. https://doi.org/10.1016/j.jclepro.2020.120124

Moshtaghian H., Bolton K., Rousta K. (2021) Challenges for Upcycled Foods: Definition, Inclusion in the Food Waste Management Hierarchy and Public Acceptability. *Foods*, 10(11), 2874. https://doi.org/10.3390/foods10112874

Moshtaghian H., Bolton K., Rousta K. (2023) Public preferences for nutritional, environmental and food safety characteristics of upcycled foods in Sweden. *International Journal of Food Science & Technology*, 58(10), 5616–5625. https://doi.org/10.1111/ijfs.16588

Moshtaghian H., Bolton K., Rousta K. (2024) Upcycled food choice motives and their association with hesitancy towards consumption of this type of food: A Swedish study. *British Food Journal*, 126(1), 48–63. https://doi.org/10.1108/BFJ-09-2022-0757

Nenciu F., Stanciulescu I., Vlad H., Gabur A., Turcu O.L., Apostol T., Vladut V.N., Cocarta M.D., Stan C. (2022) Decentralized Processing Performance of Fruit and Vegetable Waste Discarded from Retail, Using an Automated Thermophilic Composting Technology. *Sustainability*, 14(5), 2835. https://doi.org/10.3390/su14052835

Ng A. (2021) Green Investing and Financial Services: ESG Investing for a Sustainable World. In: *The Palgrave Handbook of Global Sustainability* (ed. R. Brinkmann), Cham: Springer, pp. 1–12, https://doi.org/10.1007/978-3-030-38948-2_104-1

Ojha S., Bußler S., Schlüter O.K. (2020) Food waste valorisation and circular economy concepts in insect production and processing. *Waste Management*, 118, pp. 600–609, https://doi.org/10.1016/j.wasman.2020.09.010

Page M.J., McKenzie J.E., Bossuyt P.M., Boutron I., Hoffmann T.C., Mulrow C.D., Shamseer L., Bossuyt I.B., Hoffmann T.C., Mulrow C.D., Shamseer L., Tetzlaff J.M., Akl E.A., Brennan S.E., Chou R., Glanville J., Grimshaw J.M., Hróbjartsson A., Manoj M. Lalu, Li T., Loder E.W., Mayo-Wilson E., McDonald S., McGuinness L.A., Stewart L.A., Thomas J., Tricco A.C., Welch V.A., Whiting P. (2021) The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. *Systematic Reviews*, 10(1), 89. https://doi.org/10.1186/s13643-021-01626-4

Papargyropoulou E., Lozano R., Steinberger J., Wright N., Ujang Z.B. (2014) The food waste hierarchy as a framework for the management of food surplus and food waste. *Journal of Cleaner Production*, 76, 106–115. https://doi.org/10.1016/j.jclepro.2014.04.020

Paraskevopoulou C., Vlachos D., Bechtsis D., Tsolakis N. (2022) An assessment of circular economy interventions in the peach canning industry. *International Journal of Production Economics*, 249, 108533. https://doi.org/10.1016/j.ijpe.2022.108533

Punia Bangar S., Chaudhary V., Kajla P., Balakrishnan G., Phimolsiripol Y. (2024) Strategies for upcycling food waste in the food production and supply chain. *Trends in Food Science & Technology*, 143, 104314. https://doi.org/10.1016/j.tifs.2023.104314

Rațu R.N., Veleşcu I.D., Stoica F., Usturoi A., Arsenoaia V.N., Crivei I.C., Postolache A.N., Lipşa F.D., Filipov F., Florea A.M., Chiţea M.A., Brumă I.S. (2023) Application of Agri-Food By-Products in the Food Industry. *Agriculture*, 13(8), 1559. https://doi.org/10.3390/agriculture13081559

Riesenegger L., Hübner A. (2022) Reducing Food Waste at Retail Stores — An Explorative Study. *Sustainability*, 14(5), 2494. https://doi.org/10.3390/su14052494

Roman B., Brennan R.A. (2021) Coupling ecological wastewater treatment with the production of livestock feed and irrigation water provides net benefits to human health and the environment: A life cycle assessment. *Journal of Environmental Management,* 288, 112361. https://doi.org/10.1016/j.jenvman.2021.112361

Rondeau S., Stricker S.M., Kozachenko C., Parizeau K. (2020) Understanding Motivations for Volunteering in Food Insecurity and Food Upcycling Projects. *Social Sciences*, 9(3), 27. https://doi.org/10.3390/socsci9030027

Rondoni A., Grasso S. (2021) Consumers behaviour towards carbon footprint labels on food: A review of the literature and discussion of industry implications. *Journal of Cleaner Production*, 301, 127031, https://doi.org/10.1016/j.jclepro.2021.127031

Sharma K., Aswal C., Paul J. (2023) Factors affecting green purchase behavior: A systematic literature review. *Business Strategy and the Environment*, 32(4), 2078–2092. https://doi.org/10.1002/bse.3237

Siddiqui S.A., Zannou O., Karim I., Kasmiati Awad N.M.H., Gołaszewski J., Heinz V., Smetana S. (2022) Avoiding Food Neophobia and Increasing Consumer Acceptance of New Food Trends — A Decade of Research. *Sustainability,* 14(16), 10391. https://doi.org/10.3390/su141610391

Smith P., Calvin K., Nkem J., Campbell D., Cherubini F., Grassi G., Korotkov V., Le Hoang A., Lwasa S., McElwee P., Nkonya E., Saigusa N., Soussana J.F., Taboada M.A., Manning F.C., Nampanzira D., Arias-Navarro C., Vizzarri M., House J., Roe S., Cowie A., Rounsevell M., Arneth A. (2020) Which practices co-deliver food security, climate change mitigation and adaptation, and combat land degradation and desertification? *Global Change Biology,* 26(3), 1532–1575. https://doi.org/10.1111/gcb.14878

Spratt O., Suri R., Deutsch J. (2021) Defining Upcycled Food Products. *Journal of Culinary Science & Technology*, 19(6), 485–496. https://doi.org/10.1080/15428052.2020.1790074

Tchonkouang R.D., Onyeaka H., Miri T. (2023) From Waste to Plate: Exploring the Impact of Food Waste Valorisation on Achieving Zero Hunger. *Sustainability,* 15(13), 10571. https://doi.org/10.3390/su151310571

Thorsen M., Skeaff S., Goodman-Smith F., Thong B., Bremer P., Mirosa M. (2022) Upcycled foods: A nudge toward nutrition. *Frontiers in Nutrition,* 9. https://doi.org/10.3389/fnut.2022.1071829

Tsalis G., Jensen B.B., Wakeman S.W., Aschemann-Witzel J. (2021) Promoting Food for the Trash Bin? A Review of the Literature on Retail Price Promotions and Household-Level Food Waste. *Sustainability*, 13(7), 4018. https://doi.org/10.3390/su13074018

Wendt M.-C., Weinrich R. (2023) A systematic review of consumer studies applying the Food Technology Neophobia Scale: Lessons and applications. *Food Quality and Preference*, 106, 104811. https://doi.org/10.1016/j.foodqual.2023.104811

Wu Q., Honhon D. (2023) Don't waste that free lettuce! Impact of BOGOF promotions on retail profit and food waste. *Production and Operations Management*, 32(2), 501–523. https://doi.org/10.1111/poms.13884

Zameer H., Wang Y., Yasmeen H. (2020) Reinforcing green competitive advantage through green production, creativity and green brand image: Implications for cleaner production in China. *Journal of Cleaner Production,* 247, 119119. https://doi.org/10.1016/j.jclepro.2019.119119

Zhang K., Zhao H., Wang S.C. (2022) Upcycle olive pomace as antioxidant and recycling agent in asphalt paving materials. *Construction and Building Materials,* 330, 127217. https://doi.org/10.1016/j.conbuildmat.2022.127217

Advanced Technologies for Bioeconomy: The Case of Microalgae Production

Irina Adarchenko[1]
PhD Student, adarchenok@yandex.ru

Anna Kurbatova[1]
Associate Professor, kurbatova-ai@rudn.ru

Natalia Porotnikova[2]
Associate Professor, Deputy Director, porotnikova@hse.ru

Elena Savenkova[1]
Professor, savenkova-ev@rudn.ru

Vinod Kumar[1,3]
Researcher, vinodkdhatwalia@gmail.com

Yana Skorokhodova[1]
Bachelor Student, 1032216649@pfur.ru

[1] RUDN University, 6 Miklukho-Maklaya str., Moscow, 117198, Russian Federation
[2] Institute of Ecology NRU HSE, 20 Myasnitskaya str., Moscow, 101000, Russian Federation
[3] Department of Life Sciences, Graphic Era (Deemed To Be University), Dehradun, Uttarakhand 248002, India

Abstract

This article presents a meticulous examination of the global microalgae market, analyzing opportunities and prospects rooted in the scientific and technical interest in products derived from microalgae. The research systematically assesses the potential commercialization of these products across diverse regions worldwide, identifies the most promising microalgae strains, the product types themself, and their potential applications. An integral aspect of this research involves a forward-looking market forecast. The analysis of scientific and technical interest delves into publication activity, considering the yearly output of works in Scopus-indexed journals utilizing the main keyword "microalgae". This assessment is presented chronologically, categorically, and regionally, offering a nuanced perspective on the evolution of interest over time and in different geographical contexts. The commercialization potential is regionally scrutinized with a focus on key regions conducive to the development of microalgae-based products, namely the Americas (USA), Asia-Pacific (China, Japan), and Europe (Germany). This evaluation is interlinked with the prevailing market dynamics in each region, providing a holistic understanding of the market landscape.

This article contributes original insights derived from the analysis, offering a nuanced perspective on the microalgae market. It introduces a distinctive and informed viewpoint, enriching existing knowledge of microalgae markets. By categorizing the microalgae market based on applications, including nutraceuticals and pharmaceuticals, food and beverages, cosmetics, animal feed, and biofuels, the study identifies sectors exhibiting steady growth. Notably, each of these sectors contributes to the projected average annual growth rate of 6.8 % on the global microalgae market, forecasted to reach USD 2 billion by 2030. This growth trajectory emphasizes the growing importance and potential of microalgae-derived products in various industries and the importance of developing the bioeconomy as a whole.

Introduction

Population growth together with urbanization and economic growth around the world is increasing the demand for food and energy resources, which in turn has a negative impact on the environment (Ramanauske et al., 2023). There are already serious environmental impacts such as depletion of energy and water resources, increased carbon dioxide emissions and pollution of water bodies (Moreira et al., 2023).

One of the possible ways to overcome the environmental crisis could be the application of the concept of circular economy. Realizing this, the developed countries of the world have already started their transition to circular economy, mainly focusing on the development of bioeconomy. Bioeconomy implies innovative use of sustainable renewable biological resources.

According to experts, the introduction of bioeconomy contributes to solving such important economic and environmental problems as depletion of natural resources, overuse of non-renewable resources, and climate change. The bioeconomy will also address challenges related to food security (Wydra, 2021; Machado Sierra et al., 2021; Ramírez et al., 2020; Parveen et al., 2023). Aimed at a global transition to a resource efficient and low carbon economy (Kuppan et al., 2023; Parveen et al., 2023), the bioeconomy has the potential to become a major new industry, displacing previous ones (Befort, 2020; Fernandez et al., 2021).

The Food and Agriculture Organization of the United Nations proposes to define bioeconomy as "knowledge-based production and use of biological resources, biological processes and principles of sustainable provision of goods and services in all sectors of the economy". Recently, the term "bioeconomy" has been increasingly used not only in science (Bugge et al., 2016), but also in management decisions at the state level (Pahun et al., 2018).

The European Commission (EC) expects the bioeconomic transition to have both environmental and socioeconomic benefits. Decisions on future biomass utilization pathways will strongly influence the characteristics of the future bioeconomy in terms of sustainability. (Asada et al., 2020). That said, according to (Bauer, 2018) there are various transformational pathways to transition to a bioeconomy and none of them are straightforward.

The concept of bioeconomy can be defined as an economy in which "the basic building blocks for materials, chemicals and energy are derived from renewable biological resources" (McCormick, Kautto, 2013). The use of biomass to replace synthetic products will have a positive impact on the environment and human health. For example, (Ahmad et al., 2021) reports that the concept of microalgae bioeconomy includes the use of algal biomass as an important component for the production of biofuels and other products using biorefineries. In the described example, biofuel production will be able to reduce CO2 emissions by 80%.

Microalgae are single-celled eukaryotic microscopic organisms capable of converting solar energy into chemical energy through photosynthesis. In addition, microalgae, also known as microphytes, produce about half of atmospheric oxygen and are able to utilize carbon dioxide for photoautotrophic growth. As the initial link in the food chain, microalgae provide energy to all trophic levels (Ponnuvel et al., 2023; Masojídek et al., 2023; Parveen et al., 2023; Chunzhuk et al., 2023).

Due to its rich energy content and high growth rate, research continues towards the development of technologies to enable the production of biofuels from microalgae (Hossain et al, 2019). Thus, microalgae-based fuels are environmentally friendly and have a high potential to fix carbon dioxide from the atmosphere (Onyeaka et al., 2021).

The use of bio-based packaging materials derived from various natural resources such as biomass, microorganisms or microalgae have shown high efficiency of packaging with improved physical characteristics (Kumar et al., 2022). Algae, including microalgae, provide a good alternative for natural production of many industrial products. In such production, the harm to the environment is significantly reduced. Microalgae are among the best among biomass-derived feedstocks for biopolymer production, while outperforming petroleum-based synthetic polymers. Microalgae-based biopolymer has improved mechanical properties compared to petroleum-based polymers. Thus, algae are potentially contributing to the bioeconomy leading to a circular bioeconomy on a global scale (Das et al., 2021).

According to (Khan et al., 2018; Fernandez et al., 2021) microalgae can be a rich source of carbon compounds that can be used in cosmetics, pharmaceuticals, and food supplements.

Microalgae are a rich source of carbohydrates (e.g., starch and glucose), proteins, fiber, essential acids, and vitamins B1, B2, B5, B6, B9, A, C, and E. Adding microalgae to human food has therapeutic effects on various health problems. For instance, eicosapentaenoic acid, a constituent of microalgae, promotes brain development in infants. Thus, in the context of global population growth, microalgae represent reliable substitutes for animal and plant products (Barkia et al., 2019; Garrido-Cardenas et al., 2018).

Studies in the field of medicine and pharmacology have reported high efficacy of microalgae in the prevention and treatment of many diseases of the immune, endocrine, digestive, cardiovascular and nervous systems of humans and animals. According to (Abeer et al., 2015) Spirulina Platensis and its extract have demonstrated therapeutic properties such as the ability to prevent cancer, reduce blood cholesterol levels, and provide protection against the harmful effects of radiation. Research in recent years shows that algae can also be used to target the biosynthesis of a range of compounds. For example, spirulina is capable of synthesizing iodine-containing

compounds of hormonal nature, such as thyroxine and triiodothyronine, which in turn are easily absorbed in the human body (Enzing et al., 2014).

In the pharmaceutical industry, microalgae are extensively used to produce capsule shells, diagnostic agents, vitamins, antibiotics, polyunsaturated fatty acids, and antibacterial substances. They are capable of producing toxins that block bacterial growth (Abu Zaid et al., 2015; Fernandez et al., 2021).

There is a wide range of commercial applications of algae in cosmetology because of its high content of oils, pigments, antioxidants (Kuldipsinh et al., 2023). Microalgae produce 15-100 times more oil per hectare than any other plants, and the negligible amount of lignin makes processing more efficient and easier (Maltsev et al., 2017).

In addition, the potential contribution of microalgae to emerging industries such as biomaterials, various agriculture related products, biofuel production and services such as wastewater and industrial gas treatment is described (Fernandez et al., 2021).

The global agricultural sector is actively adopting resource efficient animal husbandry and feeding technologies (Fernandez et al., 2021).

Feed enriched with microalgae biomass has a positive effect on animal physiology, improving the immune system of animals, reproductive capacity, and weight gain (Remize et al., 2021). In addition, the use of microalgae is a solution to the problem of unbalanced diets of farm animal feeding (Navarro et al., 2016).

In the USA, farms are provided with algae ponds, where animal waste is utilized using algae (Makarova et al., 2009). In particular, microalgae represent an important factor in the biological indication of environmental conditions (O'Neill, Rowan, 2022, Cid et al., 2013).

Thus, the role of microalgae in the modern world is great. Based on the above, the key applications of microalgae can be summarized as follows (Fig. 1).

Considering the emerging progress in modern biotechnology, the main focus is on the development of microalgae for the production of cost-effective bio-renewable energy sources with high added value (Singh et al., 2022).

As noted earlier, microalgae have been extensively utilized in the production of biofuels. Note that algae are characterized by rapid growth, far outpacing the growth of plant food crops (Ivanova et al., 2020). This type of biomass is grown in areas unsuitable for crop production, being a waste-free, energy clean, energy- and resource-saving way of energy production. The yield of microalgae in terms of biomass and the amount of lipids exceeds the yield of land plants by dozens of times (Vlaskin et al., 2018). As a source of bioenergy, microalgae demonstrate high efficiency under minor environmental constraints (Zhang et al., 2022). It should be noted that microalgae cultivation does not require resources such as soil, fresh water,

pesticides and fertilizers. Microalgae can be grown in both salt water and wastewater (Khan et al., 2018).

Lipids in microalgae can be utilized to produce gaseous fuels (hydrogen and biogas), liquid fuels (ethanol) and liquid hydrocarbon fuels (Sanghamitra et al., 2021).

Thus, microalgae have great potential as a low-cost and energy efficient source of biofuels. According to the modern classification of biofuels presented in the work (Chernova et al., 2010), the fuel produced using microalgae is called third generation biofuel. This type of fuel has an advantage because microalgae have a high growth rate, they do not require high quality land for their cultivation, and the lipids included in microalgae are highly productive.

The development of microalgae biomass energy at this stage includes the production of biodiesel from microalgae lipids by transesterification (Vignesh et al., 2021), the production of methane by anaerobic digestion (Qi et al., 2017), and the production of hydrocarbons or crude oil and similar substances by gasification and pyrolysis.

Despite all the above advantages, researchers have not been able to produce microalgae-based biofuels at a competitive cost at present. According to (Piligaev et al., 2014) there is a deterrent to large-scale production of third generation biofuels due to high costs compared to the production of fuel from conventional feedstocks. In addition, the reasons for low economic efficiency include such factor as lack of optimal cultivation technology (Strebkov et al., 2012).

However, the increasing interest in biofuel production during the last decade is directly related to several reasons. Firstly, the manufacture and use of biofuels is linked to the prospect of reducing carbon dioxide emissions. Secondly, there is a global increase in demand for hydrocarbon raw materials, while their reserves continue to be depleted. Specialists note that at current rates of consumption, oil reserves will be sufficient for no more than 40 years, and natural gas for 60 years. (Vorob'ev et al., 2015)

Thus, microalgae offer almost unlimited opportunities for the development of modern bioeconomy, given their metabolic flexibility and high rate of biomass yield, even when grown under harsh conditions, such as wastewater treatment or flue gas utilization. (Fernandez et al., 2021) Microalgae can play a crucial role in environmental protection due to their efficient CO_2 capture and their potential as a solution for a carbon negative economy (Mendonça et al., 2024). In turn, circular bioeconomy directs the best optimal utilization of the resulting microalgae biomass to create a sustainable and environmentally friendly system (Ahmad et al., 2021).

Considering the wide range of applications of microalgae, market research on microalgae-based products has important scientific, economic and practical significance.

Figure 1. **Applications of microalgae products**

Source: authors.
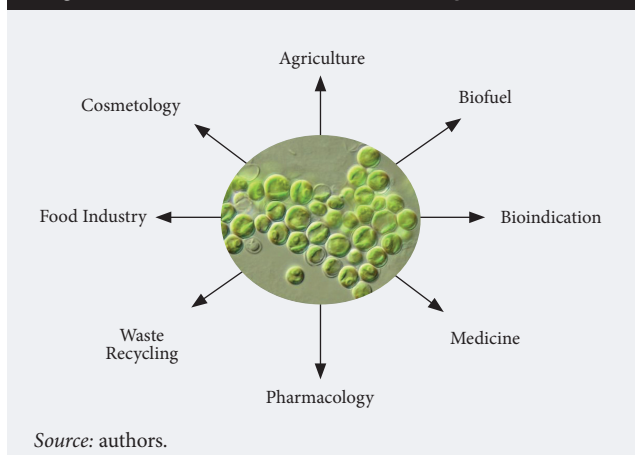
Purpose of the study

The purpose of this study is to conduct a meticulous examination of the global microalgae market with the aim of providing comprehensive insights into the opportunities and prospects arising from scientific and technical advancements in microalgae-derived products. The research seeks to systematically evaluate the potential commercialization of these products across diverse regions worldwide by identifying the most promising microalgae strains, categorizing product types, and exploring their applications.

Key objectives include:

1. *Scientific and Technical Assessment:* To gauge the level of scientific and technical interest in microalgae, the study involves a detailed analysis of publication activity in Scopus-indexed journals. This assessment is conducted chronologically, categorically, and regionally to provide a thorough understanding of the evolving landscape of microalgae research.

2. *Commercialization Potential:* The research aims to assess the commercialization potential of microalgae-based products, focusing on key regions deemed most prospective for development: the Americas (USA), the Asia-Pacific region (China, Japan), and Europe (Germany). The evaluation is intricately linked to the current market dynamics of each region.

3. *Market Forecast:* A forward-looking market forecast is integral to the study, providing insights into the anticipated growth trajectory of the global microalgae market. This forecast considers factors such as historical trends, market dynamics, and the identified commercialization potential to project the market's future size and value.

Value

This article adds significant value to the existing body of knowledge on microalgae-based products and services. By conducting a thorough literature search and reviewing available materials, the study provides a comprehensive overview of the current state of research and industry trends related to microalgae.

The region-specific analysis of commercialization potential, focusing on key regions such as the Americas, Asia-Pacific, and Europe, adds practical relevance to the research. By linking these findings to current market dynamics, the article not only identifies promising opportunities but also provides actionable insights for stakeholders in the microalgae industry.

Thus, the study can be an essential resource for researchers, industry professionals, and policymakers seeking a comprehensive understanding of the field. The projected growth rates and market forecasts presented in the article contribute valuable foresight, making it a relevant and forward-looking resource in the domain of microalgae-based products and services.
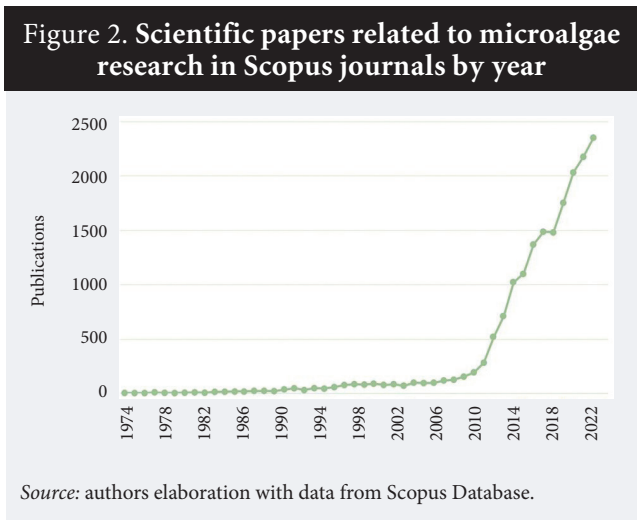
Methodology

The research methodology employed in this study involved a literature search and a comprehensive review of available materials pertaining to microalgae-based products and services. The foundation of the study was laid through a meticulous examination of scientific papers, industry reports, and other relevant publications. This literature search aimed to capture the breadth and depth of existing knowledge and insights related to microalgae and their application and provide a contextual understanding of the evolution of interest in microalgae-derived products, offering insights into the trends and shifts that have shaped the field over time.

The systematic analysis of publication activity in Scopus-indexed journals, utilizing the main keyword "microalgae", formed a crucial part of gauging scientific and technical interest. This assessment was conducted chronologically, categorically, and regionally, providing a nuanced understanding of the dynamics influencing the research landscape.

The commercialization potential of microalgae-based products was evaluated through a region-specific approach, focusing on key regions identified as most promising for development—namely, the Americas (USA), Asia-Pacific (China, Japan), and Europe (Germany). This approach allowed for a detailed examination of the current market dynamics in each region and their implications for the commercialization prospects of microalgae products.

Market Analysis

For a deeper understanding of the trends in the development of the microalgae market, it is necessary to assess the scientific and technical interest in the subject under study. Thus, a systematic literature analysis of scientific research related to the study of microalgae, presented in the form of publications in journals indexed in the international scientific citation database Scopus, showed that from 1974 to 2022, 20 472 scien-

Figure 2. Scientific papers related to microalgae research in Scopus journals by year

Source: authors elaboration with data from Scopus Database.

tific documents with the word "microalgae" in the keywords were published worldwide.

The dynamics of scientific papers on microalgae research presented in Scopus-indexed journals is presented in Fig. 2:

At the same time, for 2000-2022, the majority of scientific research falls on such countries as China (6265), USA (4231), India (3120) (Fig. 3a, 3b). The number of studies affiliated with Russian organizations and scientists is 820 (17th place in the ranking by countries).

From 2000 to 2022, a significant number of scientific papers on microalgae (12,222) were published in environmental journals. A considerable number of scientific publications are presented in journals devoted to agricultural and biological sciences (11,741), chemical engineering (8,101), biochemistry, genetics and molecular biology (7,225), and energy (6,858).

It is worth noting, however, that while at the dawn of the current millennium (2000-2009), the bulk of re-

search was in agricultural and biological sciences journals, between 2010 and 2019, more attention began to be paid to the role of microalgae in relation to environmental sciences. With the beginning of the current decade (2020-2022), the gap in favor of publications in environmental journals began to widen further (Figure 4).
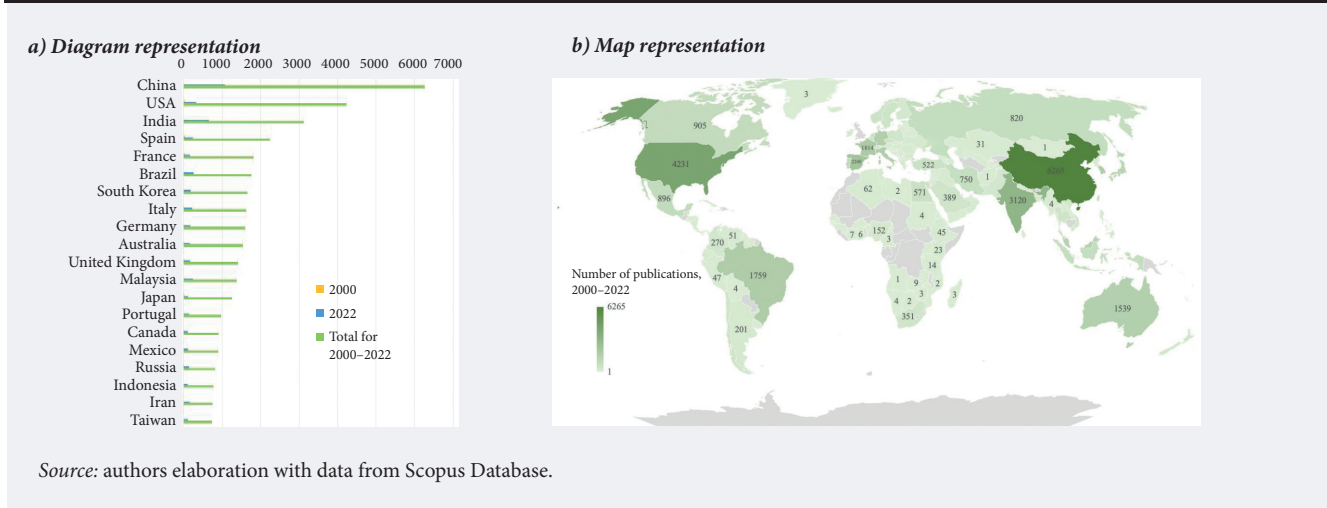
Scopus Database

This trend is primarily due to the fact that the steady increase in general awareness and responsibility towards the environment plays a significant role in shaping the scientific agenda. In addition, environmental sciences are, for the most part, the connecting link between the rest of the branches of knowledge that are in one way or another related to microalgae.

The total number of publications related to microalgae in 2000 and 2022 by branch of knowledge is presented in Figure 5:

At the same time, the majority of articles in the above analysis results are devoted to the functions of microalgae in the environment (8,962 publications), their possible use for food and chemical production (4,275 and 4,271 publications, respectively). Delving deeper into the evaluation of research topics, it is found that articles are mainly focused on pigments (1861), proteins (1847), feeds (1818), drugs (1474), biofuels (1014) and biotechnology (892). In addition, articles on niche markets in biostimulants (13), bioplastics (14), vaccines (16), biofertilizers (22) and nanotechnology (59) have recently begun to appear.

Figure 2 clearly shows a significant increase in the number of articles on this topic since 2010, which may be associated with the rapidly growing trend of microalgae application in the innovation sector of the economies of certain countries, including the use of microalgae as a raw material for biofuels.

Figure 3. Scientific papers related to microalgae research in Scopus journals by country and territory

a) Diagram representation

b) Map representation

Source: authors elaboration with data from Scopus Database.

Figure 4. **Dynamics of publication activity related to microalgae research in journals of agricultural and biological sciences and environmental sciences**

Number of publications

- 2000–2009: 793 / 1621
- 2010–2019: 6818 / 6299
- 2020–2022: 4611 / 3821

■ Environmental Science
■ Agricultural and Biological Sciences

Source: authors elaboration with data from Scopus Database.

Table 1. **Main segments of the microalgae market**

Product type
• *Spirulina* • *Chlorella* • *Pufa* • *Lutein* • Other
Microalgae strain
• *Haematococcus Pluvialis* • *Phaeodactylum Tricornutum* • *Porphyridium Cruentum* • *Nannochloropsis* • Other
Application
• Food and drinks • Food additives • Pharmaceuticals • Cosmetics and personal care • Biofuels • Fertilizers • Feeds • Other
Region
• North America (USA, Canada, Mexico) • Europe (France, Germany, UK, Italy, Spain, Netherlands, Austria, Russia) • Asia-Pacific (Japan, China, India, Malaysia, Indonesia, South Korea) • Latin America (Brazil, Argentina) • Middle East and Africa (Saudi Arabia, UAE, Israel, South Africa)

Source: authors.

It is important to note that in the data presented above, a single publication may be affiliated with several countries and scientific sectors. Nevertheless, excluding duplication of publications could lead to incorrect interpretation of publication activity indicators.

When it comes to the global microalgae market, there is a similar dynamic for the academic community presented above.

Overall, the microalgae market is segmented on the basis of product type, microalgae strain, application, and region (PMR, 2023) (Table 1).

Market classification by region

Geographically, North America accounted for the largest share of the global microalgae market in 2022, followed by Europe and Asia Pacific[1]. The large market share held by North America is mainly attributed to the huge consumption of dietary supplements among the population, strict regulation on synthetic colorants, and increasing demand for natural cosmetics and biofertilizers. All this is supplemented by the presence of key microalgae biomass producers with huge production capacity in the region, especially in the U.S. (The Insight Partners, 2021).

The microalgae market by region (2018-2021, USD million) is depicted in Figure 6:

The U.S. microalgae market is estimated to be worth $285 million by the end of 2020. The country currently accounts for 29.14% of the global market. China, the second largest economy in the world, is projected to reach an estimated market size of USD 253.5 million in 2026. Other noteworthy geographic markets include

Japan and Germany, each projected to grow at a CAGR of 4.2% and 4.7% respectively between 2020 and 2027[2].

USA

As mentioned above, the rapid pace of technological development and supportive government regulations have made North America the most promising market for the food and beverage, health and personal care sectors. Consumers in the U.S. and Canada are adopting healthy lifestyles and prefer products that offer health benefits. Thus, growing health concerns among consumers are driving the growth of the microalgae-based products market in the region. Owing to the increasing demand from customers for high quality products and services, companies are continuously focusing on innovation to serve their customers in the best possible manner. Moreover, high individual spending in North America has contributed to the growing demand for innovative food & beverages, personal care, and pharmaceutical products in the region. The growth of these industries directly influences the demand for microalgae-based products in the global market (The Insight Partners, 2021).

Favorable investment climate, elaborate investment attraction procedures, and advanced technologies have

---

[1] https://www.fao.org/in-action/sustainable-and-circular-bioeconomy/overview/en/, accessed 17.05.2024.
[2] https://www.researchandmarkets.com/reports/5790809/microalgae-global-market-report#rela1-5140359, accessed 11.09.2023.

Figure 5. **Scientific papers related to microalgae research in Scopus journals by industry (large circle - 2022, small circle - 2000)**

Source: authors elaboration with data from Scopus Database.
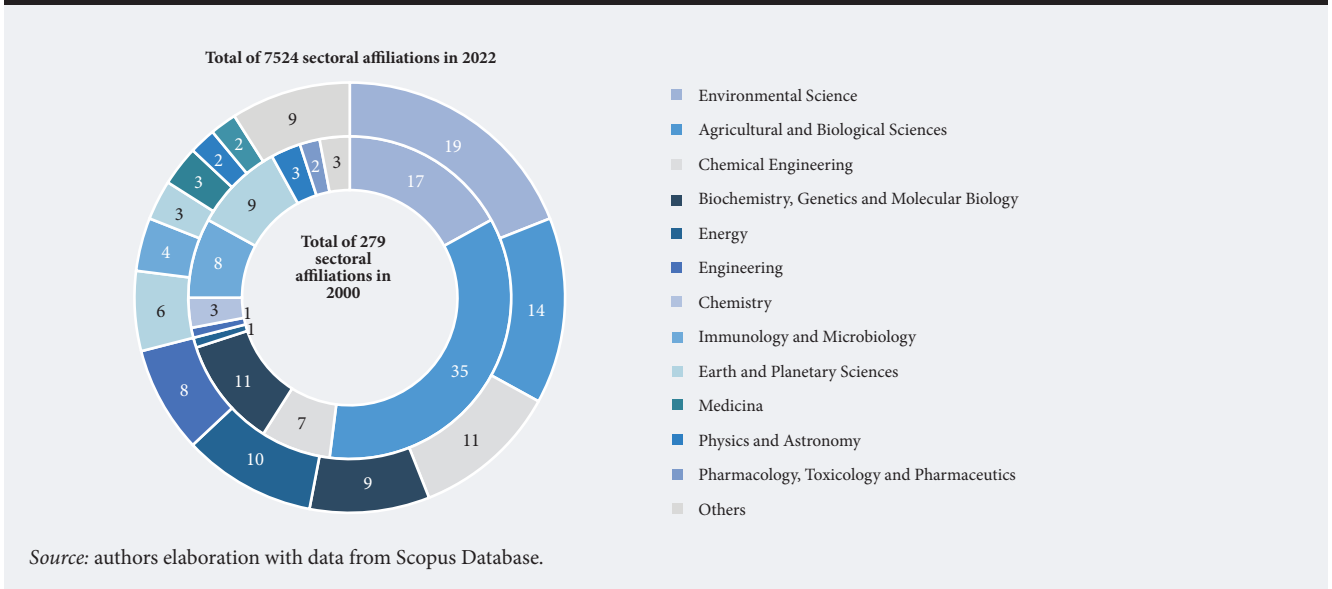
played a key role in the development of the microalgae market in the United States. Thus, the Emerging Markets Program[3], coordinated by the U.S. Department of Agriculture, provides support to U.S. agricultural producers to export their products (both traditional and innovative) to foreign markets, as well as the Borlaug Fellowship Program - aimed at supporting research and innovation, including biotechnology and GMOs[4].

In addition, government policies are expected to give even more momentum to natural ingredient producers in North America. For instance, the U.S. Food and Drug Administration (FDA) has approved the use of Lina Blue based on spirulina and beta-carotene derived from microalgae (Dunaliella salina) in candy as an alternative to synthetic colors (Chakraborty et al., 2019). Lina blue and beta-carotene extracted from Spirulina and Dunaliella salina microalgae impart blue, red, yellow or orange color to food products and are widely used in confectionery and dairy products, candy, chewing gum, ice cream and yogurt (Wang et al., 2022, Luzardo-Ocampo et al., 2021). In addition, Haematococcus pluvialis microalgae has been approved for use as a food additive ingredient in the U.S. and Canada[5].

As a result, by 2028, the market for microalgae-based products in North America is valued at USD 776.43 million (The Insight Partners, 2021) at a compound annual growth rate of 8.1% (2021-2028).

Asia-Pacific region (China, Japan)

Asia is estimated to witness the fastest CAGR in the market over a ten-year period due to the increasing use of microalgae-based products[6]. The application base of microalgae biomass is expanding and diversifying, which is encouraging manufacturers to explore opportunities to expand production capabilities (Sarwer et al., 2022). Moreover, increasing investments in the sustainability sector are expected to further boost the market growth (Khan et al., 2018).

The Chinese government is actively involved in implementing measures to promote the use of microalgae-based products, which is expected to boost the development (Chen et al., 2020). Overall, China is now one of the largest producers of microalgae biomass in the world (Chen et al., 2016).

The largest commercially produced microalgae by tonnage in China and in the world is spirulina (A. platensis and A. maxima). Spirulina was first cultivated in

Figure 6. **Microalgae market by region (2018-2021, USD million)**

Source: authorsbased on (The Insight Partners, 2021).
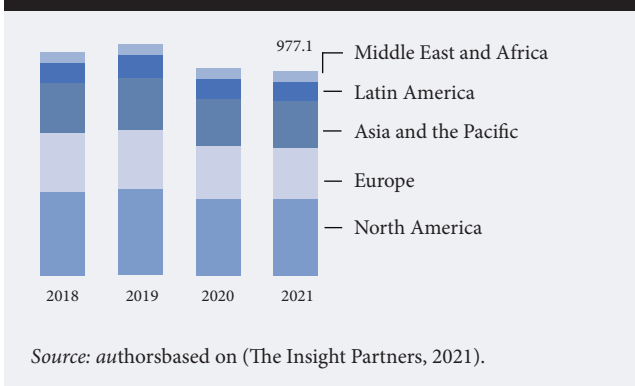
China in the 1970s, but technology limitations at the time did not lead to large-scale production. Since then, spirulina plants have been produced in almost every province and region, from southern Hainan to Inner Mongolia and from Yunnan to Zhejiang (Chen et al., 2016).

More than 60 spirulina plants with 750 ha of planting base produce 9,600 tons of dry weight of microalgae per year in China with an annual retail value of more than RMB 4 billion per year. Production costs are typically about one-tenth of the retail value, which increases when it reaches the consumer, taking into account operating profit, return on investment, marketing, formulation (e.g., tableting, etc.), packaging, delivery, distribution, advertising, retail sales, taxes, etc. (Chen et al., 2016).

Chlorella was first grown commercially in Japan as well as China in the 1960s, earlier than spirulina, but technology limitations at that time did not lead to large-scale production in China (Radmann et al., 2017, Chen et al., 2016). Over the past decade, China has also become one of the world's largest producers of chlorella, overtaking traditional production in Japan. Chlorella production is generally much smaller in volume than spirulina production, probably by a quarter, but the price per ton is much higher. Many spirulina facilities produce chlorella, usually as a smaller part of a larger spirulina production process. Chlorella production is technically more complex and expensive than spirulina because of the greater likelihood of contamination and the need for centrifuges to harvest these microscopic cells. This is in contrast to the easier collection of fibrous spirulina and fewer contamination problems due to the high bicarbonate environment. Chlorella is dried and sold similarly to spirulina as a dietary supplement, either in powder, tablet and capsule form (Chen et al., 2016).

Two other microalgae grown commercially in China are Dunaliella and Haematococcus, from whose biomass valuable carotenoids, beta-carotene and astaxanthin, respectively, are extracted. Dunaliella was first commercialized in Australia and Israel in the 1980s (Borowitzka, 2018).

The main existing market for astaxanthin is its sale as a feed additive for farmed salmon and trout to color fish meat (Stachowiak, Szulc, 2021). Meanwhile, the market price of synthetic astaxanthin is around 1000 USD/kg (Panis, Rosales Carreon, 2016).

Regarding the marketing of natural astaxanthin from microalgae, the only possible market for it is as a human food supplement, mainly because of its high selling price, almost 10 times the current price of synthetic astaxanthin (Panis, Rosales Carreon, 2016). The production of astaxanthin by Haematococcus pluvialis in China is developing rapidly, mainly in Yunnan and Hubei Province (Chen et al., 2016).

In Japan, the microalgae industry is not an industrial sector per se, as there is no direct business related to their collection, although it has potential for R&D applications such as absorbing CO_2 emissions existing in the environment. Meanwhile, there are indirect sectors related to the production of microalgae biomass that can be processed into various products (Herrador, 2016).

Japan is one of the countries with the highest investments and expectations in the microalgae industry, focusing on the production of biomass-based products to address Japan's vulnerable energy supply situation as well as to open up new markets related to food, feed, and biochemicals (such as plastics). Major players such as DENSO Corporation, Euglena Corporation, ISUZU Motors Corporation, and All Nippon Airways are involved in the production of microalgae-based projects. The Japanese government is also involved in supporting these initiatives as well as universities such as the University of Tsukuba, which is a world leader in research and development that aims to develop microalgae technologies on various plants (Herrador, 2016).

In addition, Japanese scientists are investigating whether microalgae can remove radioactive cesium, iodine, and strontium from radioactively contaminated aquatic environments and reduce radioactive contamination in the Fukushima area. It has been determined that some species can absorb up to 89.2% of cesium; 41.3% of strontium and 65.9% of iodine (Fukuda et al., 2014).

Japan's New Energy and Industrial Technology Development Organization (NEDO) published a report in 2016 highlighting the importance of using microalgae for biofuel production, using sunlight energy to convert carbon dioxide into fuel as a renewable resource. The conversion efficiency is the highest among plant species. The report notes that "in the future, in order to reduce production costs, increase productivity per unit area, and reduce costs... a system for oil collection, recovery, and purification will be finalized," also indicating that "jet fuel" for airplanes will be produced (Herrador, 2016). There are even known cases of successful implementation of a project to replace traditional airplane fuel with environmentally friendly fuel produced from microalgae. Thus, in 2021, Japan's largest airlines performed domestic commercial flights using environmentally friendly aviation fuel derived from microalgae.[7]

---

[5] https://fas.usda.gov/programs/borlaug-fellowship-program, accessed 07.01.2024.

[6] https://www.meticulousresearch.com/product/europe-microalgae-market-5491, accessed 13.05.2023.

[7] https://www.transparencymarketresearch.com/microalgae-based-products-market.html, accessed 07.01.2024.

EU (Germany)

Europe held the second largest share of the global microalgae-based products market in 2020[8]. The demand for microalgae-based products in the region is growing due to factors such as significant growth in food & beverages, animal feed, pharmaceuticals & nutraceuticals, personal care products, and other end-use industries. The region has ample opportunities for market growth owing to rapid industrial development along with increasing R&D expenditure, which is expected to generally diversify the application base of microalgae-based products, which is also expected to drive market growth. Furthermore, rapid development of manufacturing base backed by improved economic activities and better investment opportunities will also fuel the growth of microalgae-based products in the regional market (Enzing et al., 2014).

Also noteworthy is the active development of environmental agenda in Europe, primarily related to the search for alternative energy sources to achieve the goals of the Paris Agreement[9].

The EU's current policy priorities promote the transition to a sustainable economy that balances the growth of economic activity, protecting natural resources and meeting the needs of a growing world population. The EU Bioeconomy Strategy (adopted in 2012 and updated in 2018) aims to implement a sustainable closed-loop bioeconomy across Europe and encourages the strengthening and development of EU biosectors and the pursuit of sustainable food and production systems (Vázquez-Romero et al., 2022). In parallel, the EU Blue Growth Strategy highlights blue biotechnology sectors among its priority objectives (European Commission, 2022).

In addition, the European Commission's Green Deal targets priority areas where the algae sector can make a relevant contribution. For example, to the EU's goal to become climate neutral by 2050, to the protection of biodiversity, to the development of a circular economy and to the farm-to-fork strategy for sustainable development in the food sector (European Commission, 2020).

Therefore, the European Union is actively involved in various projects to explore renewable resources, bioenergy and bioprocessing, including those related to microalgae (Enzing et al., 2014).

Germany accounted for the largest share of the microalgae market in Europe in 2021. Consumers in Germany are traditionally health-conscious, sensitive to environmental concerns, and willing to pay higher prices for more natural, environmentally friendly products with minimal processing. At the same time, this interest of German consumers in health and wellness products is fueled, among other things, by government education programs, media, and advertisements promoting healthy lifestyles[10].

As a result, the high increase in citizens' awareness makes food manufacturers think about producing and distributing healthy food and beverages.

However, there are a number of restrictions in the EU that result in only a small fraction of naturally occurring microalgae species being commercially exploited. It is argued that the rate of exploitation of new species is also hampered by administrative burdens, namely the need for any new products to go through the New Foods Regulation before they can be placed on the food market. In doing so, these procedures are costly and time-consuming. Yet, a number of companies are already cultivating microalgae on an industrial scale and have an established market (Araújo et al., 2021) (Table 2):

Food supplements and nutraceuticals (24%), cosmetics (24%) and feed (19%) are the main uses of microalgae biomass, accounting for 67% of the total utilization. Meanwhile, spirulina production is mainly directed towards food, food additives and nutraceuticals, accounting for 75% of the reported uses (Araújo et al., 2021).

Although commercial production of microalgae in the EU is well established, high production costs and technological limitations, as well as gaps in scientific understanding of large-scale algal cultivation, limit the commercialization of biomass as high-value products, except for large-scale low-cost applications such as fuels (Araújo et al., 2021).

The market value of microalgae biomass varies depending on several factors such as production system, production costs (energy and labor), geographical origin, certification schemes (e.g., organic production), and stage of the value chain (e.g., B2B or B2C sector) (Lucakova et al., 2022).

Meanwhile, the value of spirulina in the B2B sector (in terms of dry weight) and chlorella varies between 25-50 €/kg and 30-70 €/kg, respectively (Araújo et al., 2021; Verdelho Vieira et al., 2022). In contrast, the value in the B2C sector for both species varies between 150 and 280 Euro/kg (higher value for small packs, finished products) (Araújo et al., 2021).

For Nannochloropsis sp., the species most suitable as feed (Qiao et al., 2019; Premachandra et al., 2023), the B2B sector price values are in the range of 30-110 €/kg, while the market value in the B2C sector (as marine phytoplankton) can reach up to 1000 €/kg (Araújo et al., 2021).

The price of H. pluvialis in the B2C sector ranges from 150 to 300 €/kg, while the B2B price of pure astaxanthin oleoresin based on pure astaxanthin is in the

---

Table 2. **Companies cultivating microalgae on an industrial scale**		
Microalgae types	**Number of producing companies**	**Production volume (tonnes)**
Spirulina	222	142
Chlorella sp.	30	82
Nannochloropsis sp.	25	21
Haematococcus pluvalis	17	66
Tysochrysis lutea	10	Less than 1
Dunaliella salina	8	2
Phaeodactylum tricornutum	8	4
Tetraselmis sp.	16	5
Scenedesmus sp.	9	n.a.
Porphyridium	7	Less than 1
Others*	37	n.a.

* *Thalassiosira sp., Acutodesmus obliquus, Chaetoceros muelleri, Cyanidium caldarium, Euglena gracilis, Odontella aurita.*

Source: (Araújo et al., 2021).

range of 6,000-8,000 €/kg (Araújo et al., 2021). New applications of microalgae biomass are facing increasing market demand and still have room for significant increases in production (Barone et al., 2023).

Description of manufacturing companies

Currently, there are a significant number of companies producing microalgae-based products worldwide. At the same time, the main competitive advantages of the leading companies include:

- availability of their own innovative developments. For example, the Israeli company Algatech has developed a unique method of mass production of microalgae for the subsequent production of astaxanthin in the desert zones of Israel[11].
- high share of leading companies in the market of the most attractive segments.

For instance, some of the key players in the algal pigments market are: Earthrise Nutritionals, LLC (U.S.), Cyanotech Corporation (U.S.), Zhejiang Binmei Biotechnology Co., Ltd. (China), Bluetec Naturals Co., Ltd. (China), BlueBioTech Int. GmbH (Germany), Algatechologies Ltd. (Israel), EID Parry (India) Limited (India), DIC Corporation (Japan), Tianjin Norland Biotech Co., Ltd (China), AlgaeCan Biotech Ltd. (Canada), AstaReal AB (Sweden), Algae Health Sciences (USA), Sochim International SpA (Italy), DD Williamson & Co., Inc. (USA), Chlostanin Nikken Nature Co. Ltd. (China) and BASF Corporation (Germany) among others.

Along with large companies - leaders of the microalgae industry, new start-ups are also being actively created. Information about them is presented in Tables 3 and 4.

Prospects for market development

According to the United Nations, the world's population is expected to grow by more than 50% from 2000 (6.14 billion people)[12] to 9.7 billion in 2050 (United Nations, 2022), and thus the amount of food produced must double to meet the needs of this population (Henchion et al., 2017). Meanwhile, meeting the protein needs of the huge population is the key aspect and growth driver of the microalgae market (Fatima et al., 2023).

Moreover, there is currently an explosive growth of interest in microalgae biotechnology globally, with start-ups and commercial enterprises successfully operating abroad to produce microalgae biomass and bioproducts from it (Garrido-Cardenas, 2018). Examples of successful realization of such projects are AlgaePARC (Amsterdam, Holland), Cyanotech (Hawaii, USA), Roquette Klötze GmbH&Co. KG (Klötze, Germany), AstaREAL AB (Gustavsberg, Sweden), Algatech (Keturah, Israel).

Scientists have also largely succeeded in unlocking the potential of microalgae for the production of a wide range of substances and materials, from cosmetics and food products to various types of plastics and biofuels (Kandasamy et al., 2022). An undeniable advantage of microalgae is the environmental friendliness of their application and production (Parveen et al., 2023).

Microalgae are increasingly being tested as nutraceuticals in the feed industry, especially in aquaculture, as a means to improve the immune response of marine animals (Khan et al., 2018; Camacho et al., 2019; Das et al., 2021). Unfortunately, commercial utilization has encountered difficulties due to high production costs associated with storage. In addition, the commercial use of microalgae as prebiotics in feed formulations has faced several challenges related to microalgae processing methods that have yet to be resolved to reduce production costs (Camacho et al., 2019).

Scaling up production is also still a major challenge. Currently, full-scale commercial microalgae-based production is only established for β-carotene and astaxanthin (Camacho et al., 2019). In spite of this, according to the bibliometric analysis carried out in the framework of this work, it is revealed that scientists are constantly conducting research to intensify the growth of microalgae and, consequently, increase their biomass.

According to a recent study by Persistence Market Research, the market for microalgae-based products is expected to grow at an average annual rate of 5.4%

---

[11] https://www.meticulousresearch.com/product/europe-microalgae-market-5491, accessed 13.05.2023.

[12] https://data.worldbank.org/indicator/SP.POP.TOTL?end=2000&start=2000, accessed on 08.01.2024.

Table 3. **List of international startups developing microalgae solutions**

Company name (Country)	Year of foundation	Description of activities
Brevel (Israel)	2022 (project establishment) 2017 (company establishment)	Produces plant protein adapted to the needs of the food industry.
Brilliant Planet (UK)	2022 (project establishment) 2017 (company establishment)	Develops a unique solution to reduce the world's carbon footprint: the company creates tanks of seawater, providing ideal breeding conditions for algae. The algae, in turn, can absorb carbon emissions in large quantities.
NewFish (New Zealand)	2020	Creation of food products using microalgae fermentation technology
Quazy Foods (Germany)	2021	Development of competitive, healthy, and sustainable microalgae-based functional ingredients while protecting aquatic ecosystems. Also sensory and nutritional optimization of microalgae strains for wide application in food products
PhycoWorks Ltd (UK)	2021	Creating valuable products from waste, accelerating the transition to a circular bioeconomy
Minus Materials (USA)	2021	Minus Materials is industrializing limestone formation. Utilizes microalgae, sunlight and seawater to capture and store carbon dioxide in the form of biogenic limestone. They reduce the formation of limestone quarries while isolating and storing carbon dioxide in the process
Algiecel ApS (Denmark)	2021	ALGIECEL utilizes natural microalgae organisms, a very compact and high-performance photobioreactor technology that fits into standard shipping containers, and a new revenue sharing business model offering carbon capture as a service
GC Lipid Tech (Canada)	2021	The company develops clean technology solutions using microalgae. GC Lipid Tech is committed to developing clean technology solutions using microalgae and providing the world with a variety of sustainable, efficient and safe biotechnologies
Ittinsect (Italy)	2020	Ittinsect specializes in the biotechnological processing of insects, microalgae and agricultural by-products to create highly effective and sustainable aquaculture feeds. The company's mission is to make aquaculture independent of marine resources by offering a product that provides fast and consistent fish growth, a robust immune system and less risk of digestive inflammation than traditional feeds. Ittinsect products produce 10% less CO2-eq emissions per kilogram than comparable conventional feeds, contributing to a lower environmental impact and helping to reduce stress on small pelagic fish
Sophie's Bionutrients (Singapore)	2017	The company grows microalgae inside bioreactors. This process can be controlled to produce protein in a matter of days. The company uses limited water and local food waste to produce protein from microalgae in metropolitan areas in many parts of the globe. Sophie's Bionutrients can also produce whole algae ingredients for a variety of food applications in the form of plant-based meats and functional foods
Realm (Germany)	2022	REALM is developing a new cost-effective approach to growing microalgae while treating wastewater and reducing freshwater demand
Algaenergy (Spain)	2009	AlgaEnergy started with the development of microalgae-based agricultural biostimulants in 2009, a world first. AlgaEnergy sells microalgae-based agricultural biostimulants worldwide. Each biostimulant consists of an optimized combination of different microalgae species in optimized proportions depending on their composition, which individually provide the necessary elements for the physiological development of the plants. The enormous biodiversity offered by microalgae, AlgaEnergy's knowledge, and the five cultivation technologies the company utilizes allow AlgaEnergy to select the ideal microalgae species depending on the desired product. But now AlgaEnergy's product line goes beyond their patented microalgae. The company offers a unique new class of crops that combine microalgae with plant nutrients and biologicals
SeaH4 (South Africa)	2021	A groundbreaking zero CO2 alternative to fossil fuels, ready for consumer use and requiring no investment in transportation infrastructure. SeaH4 fuel requires no changes to engines or distribution network
Algaementum (Portugal)	2023	Algaementum aims to create specialized cultivation sites in central-eastern Portugal in 2024. Where an abundance of sunlight, clean water and skilled human capital combine to provide unique opportunities for algae cultivation. Free from plastic, toxins and heavy metal pollution, Algaementum is committed to producing the most nutritious food (and feed) ingredients in accordance with the EU's high ethical and organic standards
Carbon Kapture (UK)	2020	Carbon Kapture is a startup focused on carbon capture and sequestration through a global network of seaweed farms

Source: authors.

and exceed a valuation of USD 5 billion by 2033 (PMR, 2023). However, according to the authors of this article, the value may be more conservative (US$2 billion by 2030), taking into account the compound annual growth rate (averaged by analysts' data at 6.8%) and the 2021 base effect of US$977.1 million.

The South Asia and East Asia market will expand at a CAGR of 7.8% and 6.8%, respectively, during the forecast period 2021-2031 (PMR, 2023). North America and Europe will continue to dominate the market with market shares of 28.8% and 27.9%, respectively (PMR, 2023).

The European market will grow significantly over the forecast period due to increasing opportunities for the use of microalgae, especially spirulina and chlorella, in the production of health and nutritional products,

Company name (Year of establishment)	Revenue (2022, thousand rubles)	Company description
Biotrek (2022)	-	Development of solutions for improving microalgae cultivation conditions using artificial intelligence
Algafood (2021)	2 233	Production of microalgae for food industry with full composition of amino acids and vitamins
Lya Vodoroslya (2023)	-	Development of technology for growing matrix and industrial cultures of different strains of marine microalgae
Ei-dzhi-ti (2020)	92	Algoremediation of water bodies to prevent their degradation due to significant anthropogenic impact and active saturation of water bodies with toxic biogenic elements (eutrophication), the unbalanced content of which contributes to the rapid development of algae and the appearance of cyanobacteria. Chlorella not only actively purifies water from organic compounds, but also from inorganic ones, for example, reduces the content of phosphorus, ammonium, formaldehyde, ammonia and others.
AA Plus Tech (2020)	-	Conversion of greenhouse gases into "healthy products" using photosynthesis of microorganisms. We are an international team with cross-industry expertise, representing a unique blend of managerial and specialized competencies in biophysics, biology, digital technologies, CO2 transformation into healthy products - dietary supplements, nutraceuticals, ingredients (algal proteins, antioxidants, food colors, PUFAs, etc.).The project is based on a cloud-based management system using AI and continuous remote non-invasive diagnostics functions, as well as continuous end-to-end accounting of CO2 equivalent in the final product.
TSVT (2021)	375	Design and manufacture of bioreactors and, on their basis, multiplatform reactor biostations. The key technology is the formation of a controlled gas vortex, which results in gentle, non-contact mixing of the culture medium and the useful substance
Algavitapro (2018)	32 724	Genetic sequencing services. Creation and market launch of an agricultural feed additive combining the properties of a prebiotic (green microalgae chlorella) and orexigen (functional peptide rubiskolin-6), which is able to increase average daily feed intake and conversion, weight gain and final weight of livestock, thus improving the economic efficiency of agricultural enterprises and farms.
Yar Lain (2015)	111 460	Development of production of organo-mineral fertilizer Chudorost based on microalgae biomass
Novye Pishchevye Biotekhnologii (2020)	-	Development of bioavailable nutraceuticals and methods of their targeted delivery for use in functional nutrition based on carotenoid extracts of Chlorella microalgae (core), biodegradable material (shell), and technologies of food products for functional nutrition with their use
Nikafresh (2020)	-	Development of innovative technology of nano-encapsulated carotenoids with high bioavailability and resistant to temperature and UV influences

Table 4. **List of Russian startups developing microalgae solutions**

Source: authors.

the shift away from synthetic dyes, growing demand for natural blue dyes, and increasing investments in the phycocyanin industry[13]. In addition, the European Union is investing in the microalgae market to achieve its goal of creating renewable energy and reducing carbon dioxide emissions. The European Commission is collaborating with several projects to improve the biofuel production system. Increased EU funding for microalgae research and development and implementation of standardization methods for the production and use of microscopic algae based products and ingredients in various industries would help the EU market to flourish (Kuech et al., 2023).

As mentioned above, the dietary supplements and pharmaceuticals segment will account for the largest market share, however, the animal feed and aquaculture segment is expected to have a significant compound annual growth rate due to the shift in consumer focus towards more nutritious feed products (PMR, 2023).

Also, production of lutein used as a food and feed additive could be another promising area of growth for the microalgae market (Lin et al., 2015). Among others, lutein has antioxidant properties, anti-cancer effects, promotes the development of infants' nervous system (Hu et al., 2018), and plays an important role in preventing cataracts (Manayi et al., 2016).

Sales of microalgae lutein-based products are expected to reach USD 450 million by 2027 (Saha et al., 2020) at a compound annual growth rate of around 6.10% (Saha et al., 2020; Fu et al., 2023).

Figure 7. **Microalgae market (2020 small circle fact and 2028 large circle forecast)**

Spirulina
Chlorella
Astaxantin
Beta-carotine
Other

*Source: au*thors based on (The Insight Partners, 2021).

---
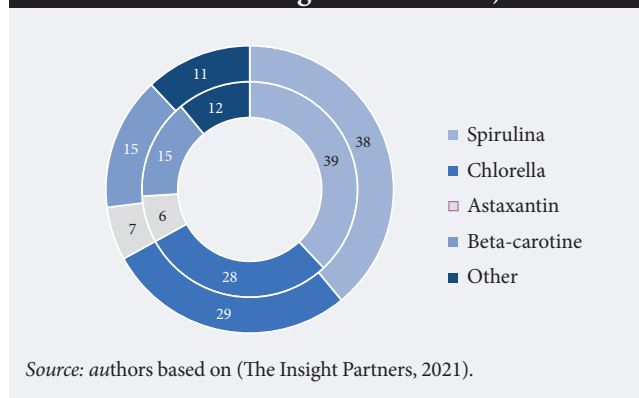
[13] https://www.cbi.eu/market-information/natural-ingredients-health-products/chlorella-and-spirulina/market-potential, accessed on 08.01.2024.

The market for microalgae-based products by microalgae species in 2020 (small circle) and 2028 (large circle) can be reflected as follows (The Insight Partners, 2021) (Figure 7).

Conclusion

Microalgae are a promising "agricultural crop" that plays the most important role in the functioning of the entire biosphere. Recently, their industrial production has attracted more and more attention, as they find their application in different spheres of national economy. These include the production of food, fodder, fertilizers, as well as a new promising direction - biofuel production.

Market trends and the growing interest of consumers to natural and healthy products forced scientists and business representatives to develop new products with functional ingredients. Microalgae have been recognized as a source of functional ingredients with beneficial health effects as these microorganisms produce polyunsaturated fatty acids, polysaccharides, natural pigments, essential minerals, vitamins, enzymes, and bioactive peptides.

The microalgae market size in 2021 was valued at USD 977 million, with an average annual market growth rate of 6,8% projected. Thus, in the authors' view, by the end of 2030, microalgae related companies are projected to generate over USD 2 billion in revenue.

The market for microalgae-based products in South Asia and East Asia is expected to expand at a CAGR of 7.8% and 6.8%, respectively, during the forecast period 2021-2031. However, North America and Europe will remain dominant in the market with market shares of 28.8% and 27.9%, respectively.

Therefore, the production of microalgae-based products is a dynamic, multi-sectoral market with huge potential in many sectors of the economy.

References

Abeer A.Z., Hammad D.M., Sharaf E.M. (2015) Antioxidant and Anticancer Activity of Spirulina Platensis Water Extracts. *International Journal of Pharmacology*, 11 (7), 846–851. https://doi.org/10.3923/ijp.2015.846.851

Abu Zaid A.A., Hammad D.M., Sharaf E.M. (2015) Antioxidant and anticancer activity of spirulina platensis water extracts. *International Journal of Pharmaceutics*, 11, 846–851. https://doi.org/10.3923/ijp.2015.846.851

Ahmad I., Abdullah N., Iwamoto K., Yuzir A. (2021) The Contribution of Microalgae in Bio-refinery and Resource Recovery: A Sustainable Approach Leading to Circular Bioeconomy. *Chemical Engineering Transactions*, 89, 391–396. https://doi.org/10.3303/CET2189066

Araújo R., Vázquez Calderón F., Sánchez López J.S., Azevedo I.C., Bruhn A., Fluch S., Garcia Tasende M., Ghaderiardakani F., Ilmjärv T., Laurans M., Mac Monagail M., Mangini S., Peteiro C., Rebours C., Stefansson T., Ullmann J. (2021) Current Status of the Algae Production Industry in Europe: An Emerging Sector of the Blue Bioeconomy. *Frontiers in Marine Science*, 7, 626389. https://doi.org/10.3389/fmars.2020.626389

Asada R., Cardellini G., Mair-Bauernfeind C., Wenger J., Haas V., Holzer D., Stern T. (2020) Effective bioeconomy? A MRIO-based socioeconomic and environmental impact assessment of generic sectoral innovations. *Technological Forecasting and Social Change*, 153, 119946. https://doi.org/10.1016/j.tec hfore.2020.119946

Barkia I., Saari N., Manning S.R. (2019) Microalgae for High-Value Products Towards Human Health and Nutrition. *Marine Drugs*, 17(5), 304. https://doi.org/10.3390/md17050304

Bauer F. (2018) Narratives of biorefinery innovation for the bioeconomy: Conflict, consensus or confusion? *Environmental Innovation and Societal Transitions*, 28, 96–107. https://doi.org/10.1016/j.eist.2018.01.005

Befort N. (2020) Going beyond definitions to understand tensions within the bioeconomy: The contribution of sociotechnical regimes to contested fields. *Technological Forecasting and Social Change*, 153, 119923. https://doi.org/10.1016/j.techfore.2020.119923

Borowitzka M.A. (2018) Biology of Microalgae. In: *Microalgae in Health and Disease Prevention* (eds. I.A. Levine, J. Fleurence), Cambridge, MA: Academic Press, pp. 23–72. https://doi.org/10.1016/B978-0-12-811405-6.00003-7

Bugge M.M., Hansen T., Klitkou A. (2016) What is the bioeconomy? A review of the literature. *Sustainability*, 8(7), 691. https://doi.org/10.3390/su8070691

Camacho F., Macedo A., Malcata F. (2019) Potential Industrial Applications and Commercialization of Microalgae in the Functional Food and Feed Industries: A Short Review. *Marine Drugs*, 17(6), 312. https://doi.org/10.3390/md17060312

Chakraborty C., Pinaki R., Manasi R., Chatterjee R. (2019) Applications of bio-colour in dairy industry. *The Pharma Innovation Journal*, 8(1), 126–138.

Chen H., Wang X., Wang Q. (2020) Microalgal biofuels in China: The past, progress and prospects. *GCB Bioenergy,* 12(12), 1044–1065. https://doi.org/10.1111/gcbb.12741

Chen J., Wang Y., Benemann J., Zhang X., Hu H., Qin S. (2016) Microalgal industry in China: Challenges and prospects. *Journal of Applied Phycology*, 28, 715–725. https://doi.org/10.1007/s10811-015-0720-4

Chernova N.I., Korobkova T.P., Kiseleva S.V., Zaytsev S.I., Radomskii N.V. (2012) Microalgae as source of energy: current situation and perspectives of use. In: *Sustainable Manufacturing* (ed. G. Seliger), Heidelber, Dordrecht, London, New York: Springer, pp. 221–224. https://doi.org/10.1007/978-3-642-27290-5_34

Chunzhuk E., Grigorenko A., Kiseleva S., Chernova N., Vlaskin M., Ryndin K., Butyrin A., Ambaryan G., Dudoladov A. (2023) Effects of Light Intensity on the Growth and Biochemical Composition in Various Microalgae Grown at High CO2 Concentrations. *Plants,* 12. 3876. https://doi.org/10.3390/plants12223876

Cid A., Prado R., Rioboo C., Suarez-Bregua P., Herrero C. (2013) Use of microalgae as biological indicators of pollution: Looking for new relevant cytotoxicity endpoints. In: *Microalgae: Biotechnology, Microbiology and Energy* (ed. M.N. Johnsen), New York: Nova Science Publishers, pp. 311–323.

Das P., Nagappan S., AbdulQuadir M., Thaher M., Khan S., Mahata C., Hareb Al-Jabri, Vatland A.K., Kumar G. (2021) Potential of microalgae as a sustainable feed ingredient for aquaculture. *Journal of Biotechnology*, 341, 1–20. https://doi.org/10.1016/j.jbiotec.2021.09.003

Enzing C., Ploeg M., Barbosa M., Sijtsma L., Vigani M., Parisi C., Rodriguez Cerezo E. (2014) *Microalgae-based products for the food and feed sector: An outlook for Europe*, Luxembourg: Publications Office of the European Union.

European Commission (2020) *Farm to Fork Strategy. For a fair, healthy and environmentally-friendly food system*, Brussels: European Commission.

European Commission (2022) *EU Bioeconomy Strategy Progress Report. European Bioeconomy policy: stocktaking and future developments* (Report COM (2022) 283 final), Brussels: European Commission.

Fatima N., Emambux M.N., Olaimat A.N., Stratakos A., Nawaz A., Wahyono A., Gul K., Park J., Hafiz Muhammad Shahbaz H.M. (2023) Recent advances in microalgae, insects, and cultured meat as sustainable alternative protein sources. *Food and Humanity*, 1, 731–741. https://doi.org/10.1016/j.foohum.2023.07.009

Fernandez F.G.A., Reis A., Wijffels R.H., Barbosa M., Verdelho V., Llamas B. (2021) The role of microalgae in the bioeconomy. *New Biotechnology*, 61, 99–107. https://doi.org/10.1016/j.nbt.2020.11.011

Fu Y., Wang Y., Yi L., Liu J., Yang S., Liu B., Chen F., Sun H. (2023) Lutein production from microalgae: A review. *Bioresource Technology*, 376, 128875. https://doi.org/10.1016/j.biortech.2023.128875

Fukuda S.Y., Iwamoto K., Atsumi M., Yokoyama A., Nakayama T., Ishida K., Inouye I., Shiraiwa Y. (2014) Global searches for microalgae and aquatic plants that can eliminate radioactive cesium, iodine and strontium from the radio-polluted aquatic environment: A bioremediation strategy. *Journal of Plant Resources*, 127(1), 79–89. https://doi.org/10.1007/s10265-013-0596-9

Garrido-Cardenas J.A., Manzano-Agugliaro F., Acien-Fernandez F.G., Molina-Grima E. (2018) Microalgae research worldwide. *Algal Research*, 35, 50–60.

Gururani P., Bhatnagar P., Kumar V., Vlaskin M.S., Grigorenko A.V. (2022) Algal Consortiums: A Novel and Integrated Approach for Wastewater Treatment. *Water*, 14(22), 3784. https://doi.org/10.3390/w14223784

Henchion M., Hayes M., Mullen A.M., Fenelon M., Tiwari B. (2017) Future Protein Supply and Demand: Strategies and Factors Influencing a Sustainable Equilibrium. *Foods*, 6(7), 53. https://doi.org/10.3390/foods6070053

Herrador M. (2016) *The Microalgae/Biomass Industry in Japan – An Assessment of Cooperation and Business Potential with European Companies*, Tokyo: EU-Japan Centre for Industrial Cooperation.

Hossain N., Mahlia T.M.I., Saidur R. (2019) Latest development in microalgae-biofuel production with nano-additives. *Biotechnology for Biofuels and Bioproducts*, 12, 125. https://doi.org/10.1186/s13068-019-1465-0

Hu J., Nagarajan D., Zhang Q., Chang J.-S., Lee D.-J. (2018) Heterotrophic cultivation of microalgae for pigment production: A review. *Biotechnology Advances*, 36(1), 54–67. https://doi.org/10.1016/j.biotechadv.2017.09.009

Kandasamy S., Zhang B., He Z., Bhuvanendran N., Elseesy A., Wang Q., Narayanan M., Thangavel P., Dar M. (2022) Microalgae as a multipotential role in commercial applications: Current scenario and future perspectives. *Fuel*, 308, 122053. https://doi.org/10.1016/j.fuel.2021.122053

Khan M.I., Shin J.H., Kim J.D. (2018) The promising future of microalgae: Current status, challenges, and optimization of a sustainable and renewable industry for biofuels, feed, and other products. *Microbial Cell Factories*, 17, 36. https://doi.org/10.1186/s12934-018-0879-x

Kuech A., Breuer M., Popescu I. (2023) *Research for PECH Committee – The future of the EU algae sector*, Brussels: European Parliament.

Kuldipsinh C., Tiwari N., Patani P. (2023) Alage: An Extensive Analysis Of Its Role In The Cosmetic Landscape. *Journal of Population Therapeutics & Clinical Pharmacology*, 30(1), 3826. https://doi.org/10.53555/jptcp.v30i1.3826

Kumar K.J., Gururani P., Vlaskin M.S., Parveen A., Nanda M., Kurbatova A., Gautam P., Grigorenko A.V. (2022) Bio-flocculation of oleaginous microalgae integrated with municipal wastewater treatment and its hydrothermal liquefaction for biofuel production. *Environmental Technology & Innovation*, 26, 102340. https://doi.org/10.1016/j.eti.2022.102340

Kuppan P., Sudharsanam A., Venkateswarlu K., Megharaj M. (2023) Solar technology–closed loop synergy facilitates low-carbon circular bioeconomy in microalgal wastewater treatment. *Clean Water*, 6, 43. https://doi.org/10.1038/s41545-023-00256-8

Lin J.-H., Lee D.-J., Chang J.-S. (2015) Lutein production from biomass: Marigold flowers versus microalgae. *Bioresource Technology*, 184, 421–428. https://doi.org/10.1016/j.biortech.2014.09.099

Lucakova S., Branyikova I., Hayes M. (2022) Microalgal Proteins and Bioactives for Food, Feed, and Other Applications. *Applied Sciences*, 12, 4402. https://doi.org/10.3390/app12094402

Luzardo-Ocampo I., Ramírez-Jiménez A.K., Yañez J., Mojica L., Luna-Vital D.A. (2021) Technological Applications of Natural Colorants in Food Systems: A Review. *Foods*, 10, 634. https://doi.org/10.3390/foods10030634

Machado Sierra E., Serrano M.C., Manares A., Guerra A., Aranguren Díaz Y. (2021) Microalgae: Potential for Bioeconomy in Food Systems. *Applied Sciences*, 11, 11316. https://doi.org/10.3390/app112311316

Makarova E.I., Oturina I.P., Sidyakin A.I. (2009) Applied aspects of the use of microalgae – inhabitants of aquatic ecosystems. *Ecosystems*, 1(20), 120–133.

Maltsev Y.I., Konovalenko T.V., Barantsova I.A., Maltseva I.A., Maltseva K.I. (2017) Prospects of using algae in biofuel production. *Regulatory Mechanisms in Biosystems*, 3(8), 455–460. https://doi.org/10.15421/021770

Manayi A., Abdollahi M., Raman T., Nabavi S.F., Habtemariam S., Daglia M., Nabavi S.M. (2016) Lutein and cataract: From bench to bedside. *Critical Reviews in Biotechnology*, 36(5), 829–839. https://doi.org/10.3109/07388551.2015.1049510

Masojídek J., Lhotský R., Štěrbová K., Zittelli C.G., Torzillo G. (2023) Solar bioreactors used for the industrial production of microalgae. *Applied Microbiology and Biotechnology*, 107, 1-20. https://doi.org/10.1007/s00253-023-12733-8

McCormick K., Kautto N. (2013) The bioeconomy in Europe: An overview. *Sustainability*, 5(6), 2589–2608 https://doi.org/10.3390/su5062589

Mendonça I., Faria M., Rodrigues F., Cordeiro N. (2024) Microalgal-based industry vs. microplastic pollution: Current knowledge and future perspectives. *Science of The Total Environment*, 909, 168414. https://doi.org/10.1016/j.scitotenv.2023.168414

Moreira J.B., Duarte S.T., Duarte J.S., Bezerra P.Q.M., Greque de Morais M., Vieira Costa J.A. (2023) Role of microalgae in circular bioeconomy: From waste treatment to biofuel production. *Clean Technologies and Environmental Policy*, 25, 427–437. https://doi.org/10.1007/s10098-021-02149-1

Navarro F., Forján E., Vázquez M., Montero Z., Bermejo E., Castaño M.Á., Toimil A., Chagüaceda E., García-Sevillano M.Á., Sánchez M., Domínguez M.J., Pásaro R., Garbayo I., Vílchez C., Vega J.M. (2016) Microalgae as a safe food source for animals: Nutritional characteristics of the acidophilic microalga *Coccomyxa onubensis*. *Food and Nutrition Research*, 60, 30472. https://doi.org/10.3402/fnr.v60.30472

O'Neill E.A., Rowan N.J. (2022) Microalgae as a natural ecological bioindicator for the simple real-time monitoring of aquaculture wastewater quality including provision for assessing impact of extremes in climate variance – A comparative case study from the Republic of Ireland. *Science of the Total Environment*, 802, 149800. https://doi.org/10.1016/j.scitotenv.2021.149800

Onyeaka H., Miri T., Obileke K.C., Hart A., Anumudu C., Zainab T. (2021) Minimizing carbon footprint via microalgae as a biological capture. *Carbon Capture Science & Technology*, 1, 100007. https://doi.org/10.1016/j.ccst.2021.100007

Pahun J., Fouilleux E., Daviron B. (2018) De quoi la bioéconomie est-elle le nom? Genèse d'un nouveau référentiel d'action publique. *Natures Sciences Sociétés*, 26, 3–16. https://doi.org/10.1051/nss/2018020

Panis G., Rosales Carreon J. (2016) Commercial astaxanthin production derived by green alga Haematococcus pluvialis: A microalgae process model and a techno-economic assessment all through production line. *Algal Research*, 18, 175–190. https://doi.org/10.1016/j.algal.2016.06.007

Parveen A., Bhatnagar P., Gautam P., Bisht B., Nanda M., Kumar S., Vlaskin M.S., Kumar V. (2023) Enhancing the bio-prospective of microalgae by different light systems and photoperiods. *Photochemical & Photobiological Sciences*, 22(11), 2687–2698. https://doi.org/10.1007/s43630-023-00471-9

Piligaev A.V., Samoilova Y.I., Sorokina K.N. (2014) Current state and prospects of development of biofuel production from microalgae. *Agricultural sciences and agroindustrial complex at the turn of the century*, 8, 21–27 (in Russian).

PMR (2023) *Microalgae-based Products Market. Market study on microalgae-based products: market progressing on back of demand for more efficient animal feed solutions. Microalgae market segmented by spirulina, Chlorella, Dunaliella Salina product in food and feed industry, pharmaceutical industry, chemical industry*, London: Persistence Market Research.

Ponnuvel D., Sowndhararajan K., Kim S. (2023) A Review of the Harvesting Techniques of Microalgae. *Water,* 15, 3074. https://doi.org/10.3390/w15173074

Premachandra E., Balasooriya W., Premarathna M., Ekanayaka I. (2023) Nannochloropsis sp.: Culturing and Potential for Fish Feed Production. *Photochemical & Photobiological Sciences,* 22, 2687–2698. https://doi.org/10.1007/s43630-023-00471-9

Priya N., Deora P.S., Verma Y., Muhal R.A., Goswami C., Singh T. (2022) Biofuels: An alternative to conventional fuel and energy source. *Materials Today: Proceedings*, 48(5), 1178–1184. https://doi.org/10.1016/j.matpr.2021.08.227

Qi Y., Zhang X.J., Renier N., Wu Z., Atkin T., Sun Z., Ozair M.Z., Tchieu J., Zimmer B., Fattahi F., Ganat Y., Azevedo R., Zeltner N., Brivanlou A.H., Karayiorgou M., Gogos J., Tomishima M., Tessier-Lavigne M., Shi S.H., Studer L. (2017) Combined small-molecule inhibition accelerates the derivation of functional cortical neurons from human pluripotent stem cells. Nature Biotechnology, 35(2), 154–163. https://doi.org/10.1038/nbt.3777

Qiao H., Hu D., Ma J., Wang X., Wu H., Wang J. (2019) Feeding effects of the microalga Nannochloropsis sp. on juvenile turbot (Scophthalmus maximus L.). *Algal Research,* 41, 101540. https://doi.org/10.1016/j.algal.2019.101540.

Radmann E.M., Reinehr C.O., Costa J.A.V. (2007) Optimization of the repeated batch cultivation of microalga Spirulina platensis in open raceway ponds. *Aquaculture,* 265(1–4), 118–126. https://doi.org/10.1016/j.aquaculture.2007.02.001

Ramanauske N., Balezentis T., Streimikiene D. (2023) Biomass use and its implications for bioeconomy development: A resource efficiency perspective for the European countries. *Technological Forecasting and Social Change*, 193, 122628. https://doi.org/10.1016/j.techfore.2023.122628

Ramírez B.D.G., Valencia J.U.S., Arbelaez A.F.A., Herrera J.M., Rojano B.A. (2020) Oxidative, sensory and fatty acid profile evaluation of a yogurt with docosahexaenoic acid (Dha) extracted from microalgae oil. *Revista Chilena de Nutrición*, 47, 568–579.

Remize M., Brunel Y., Silva J.L., Berthon JY, Filaire E. Microalgae n-3 PUFAs Production and Use in Food and Feed Industries. *Marine Drugs,* 19(2), 113. https://doi.org/10.3390/md19020113

Saha S.K., Ermis H., Murray P. (2020) Marine Microalgae for Potential Lutein Production. *Applied Sciences*, 10, 6457. https://doi.org/10.3390/app10186457

Sanghamitra P., Mazumder D., Mukherjee S. (2021) Treatment of wastewater containing oil and grease by biological method-a review. *Journal of Environmental Science and Health, Part A,* 56, 394–412. https://doi.org/10.1080/10934529.2021.1884468

Sarwer A., Hamed S.M., Ahmed I. Osman A.I., Jamil F., Al-Muhtaseb A.H., Alhajeri N.S., Rooney D.W. (2022) Algal biomass valorization for biofuel production and carbon sequestration: A review. *Environmental Chemistry Letters*, 20, 2797–2851. https://doi.org/10.1007/s10311-022-01458-1

Singh A., Kushwaha A., Goswami S., Tripathi A., Bhasney S.M., Goswami L., Hussain C.M. (2022) Roadmap from microalgae to biorefinery: A circular bioeconomy approach. In: *Trends to Approaching Zero Waste* (eds. C.M. Hussain, S. Singh, L. Goswami), Amsterdam: Elsevier, pp. 339–360. https://doi.org/10.1016/B978-0-323- 85403-0.00006-2

Stachowiak B., Szulc P. (2021) Astaxanthin for the Food Industry. *Molecules,* 26(9), 2666. https://doi.org/10.3390/molecules26092666

Strebkov, D.S., Shchekochikhin, Y.M., Ross, M.Y. (2012) Main directions of biotechnological development of renewable energy for the production of alternative fuels from plant raw materials. *Vestnik VIESKh,* 1(6), 43–50 (in Russian).

The Insight Partners (2021) *Trends and growth analysis reports related to North America Microalgae-Based Products Market*, Pune (India): The Insight Partners.

United Nations (2022) *World Population Prospects 2022: Summary of Results* (Report UN DESA/POP/2022/TR/NO. 3), Vienna: United Nations.

Vázquez-Romero B., Perales J.A., Pereira H., Barbosa M., Ruiz J. (2022). Techno-economic assessment of microalgae production, harvesting and drying for food, feed, cosmetics, and agriculture. *Science of The Total Environment*, 837, 155742. https://doi.org/10.1016/j.scitotenv.2022.155742

Verdelho Vieira V., Cadoret J.-P., Acien F.G., Benemann J. (2022) Clarification of Most Relevant Concepts Related to the Microalgae Production Sector. *Processes*, 10, 175. https://doi.org/10.3390/pr10010175

Vignesh K.S., Anandakumar I., Ranjan R., Borah D. (2021) Flood vulnerability assessment using an integrated approach of multi-criteria decision-making model and geospatial techniques. *Modeling Earth Systems and Environment*, 7, 767–781. https://doi.org/10.1007/s40808-020-00997-2

Vlaskin M.S., Vladimirov G.N. (2018) Hydrothermal Carbonization of Organic Components from Municipal Solid Waste. *Theoretical Foundations of Chemical Engineering,* 52(6), 996–1003. https://doi.org/10.1134/S0040579518050421

Vorobyev V. V., Kozhevnikov Y. A., Shchekochikhin Y. M. (2015) Microalgae for the production of energy biomass and fuel. *Innovations in Agriculture*, 2, 235–243 (in Russian).

Wang J., Hu X., Chen J., Wang T., Huang X., Chen G. (2022) The Extraction of β-Carotene from Microalgae for Testing Their Health Benefits. *Foods*, 11, 502. https://doi.org/10.3390/foods11040502

Wydra S., Hüsing B., Köhler J., Schwarz A., Schirrmeister E., Voglhuber-Slavinsky A. (2021) Transition to the bioeconomy – Analysis and scenarios for selected niches. *Journal of Cleaner Production,* 294, 126092. https://doi.org/10.1016/j.jclepro.2021.126092

Zhang S., Zhang L., Xu G., Li F., Li X. (2022) A review on biodiesel production from microalgae: Infuencing parameters and recent advanced technologies. *Frontiers in Microbiology,* 13, 970028. https://doi.org/10.3389/fmicb.2022.970028
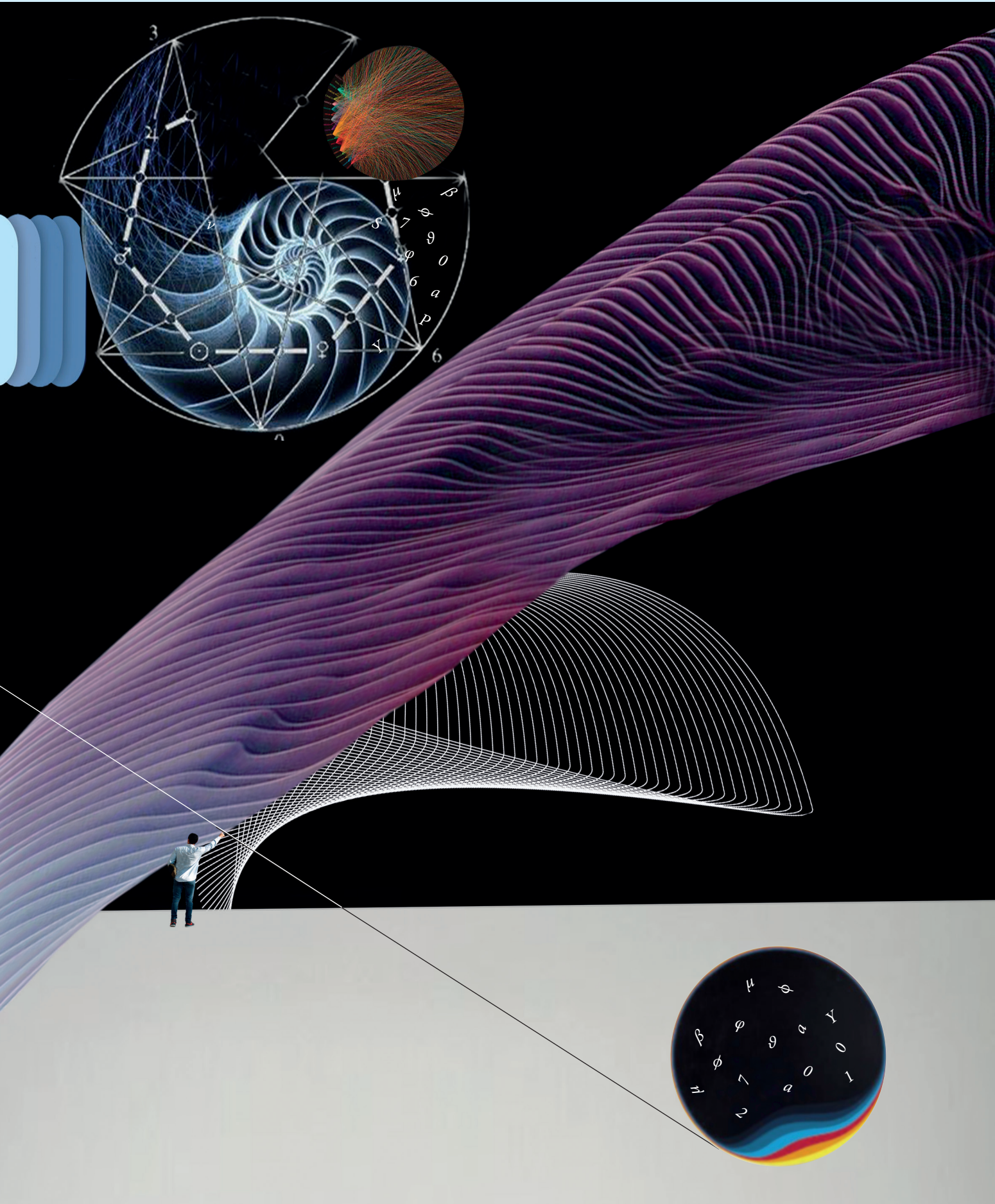
Overcoming Internal and External Barriers for the Innovative Development of Businesses

Valeriya Vlasova [a]

Head of Unit for Innovation Studies, Research Fellow, Associate Professor, Institute for Statistical Studies and Economics of Knowledge (ISSEK), vvvlasova@hse.ru

Kseniia Boiko [b]

Senior Lecturer, Department of Management, kboiko@hse.ru

Tatiana Kuznetsova [a]

Academic Supervisor, ISSEK Centre for Science, Technology, Innovation and Information Policy, tkuznetzova@hse.ru

National Research University Higher School of Economics
[a] 11, Myasnitskaya str., Moscow 101000, Russian Federation
[b] 16, Souza Pechatnikov str., Saint Petersburg 190008, Russian Federation

Abstract

Recent years have become a stress test for Russian innovative business due to increased internal and external barriers to development. In order to assess the adaptive capacity of firms and their readiness to continue innovation activities in times of crisis, this paper proposes an approach to identify and systematize the attitude and expectations of the business community towards the changing framework conditions for innovation. The innovation climate is measured as a set of 47 factors combined into 8 groups: markets, competitive environment, material base, availability of human and financial resources, quality of infrastructure, government regulation and social environment. The analysis is based on the results of a specialized survey of 1121 high-tech manufacturing and service firms, conducted between January and March 2022. The results show that business perceptions of framework conditions for innovation and areas of inefficiency vary weakly across industries, but are strongly related to firms' patterns of innovative behavior. Non-innovative firms are the most pessimistic in their assessments. The key barriers to innovation are related to the quality of government regulation and the availability of external financing. The results obtained allow expanding the understanding of the peculiarities of business adaptation to external constraints and formulate some recommendations for innovation policy.

Introduction

Many countries see achieving sustainable economic growth and technological sovereignty as key strategic goals. For Russia, faced with unprecedented sanctions pressure coupled with other destructive external factors and internal barriers hindering development, these goals have become critical. The effectiveness of the entire national economy is now under threat, along with economic actors' activities, and operation of management systems, models, and tools at all levels.

As international experience shows, in a crisis situation, businesses change their behavioural patterns to launch adaptation processes, trying to balance growth strategies (strengthening the advantages to increase sustainability, competitiveness, and performance) and survival (keeping within tolerable limits the impact of negative external conditions, increasingly constraining and occasionally overwhelming). Many companies choose extremely conservative strategies, mainly relying on own experience in dealing with emerging problems, such as, e.g., during the pandemic. At the same time adaptation methods, and factors affecting their choice, are very diverse, and depend on organisations' basic characteristics (size, age, activity area), sectoral and cultural/historical specifics, and features of the national business environment which determine the conditions for doing business and creating innovations (Paunov, 2012).

The relevant scientific literature is mainly focused on the changing framework conditions for doing business, i.e. the external context of companies' operations. This context cannot be controlled by company management, but it significantly affects management decision-making, in particular the willingness and ability to implement technological solutions, develop new products, and participate in global value chains (Baier, Zenker, 2022; Brancati et al., 2017). The importance of how quickly companies respond to changes, reconfigure their strategies, and adjust behaviour patterns is also noted. Both companies, and public authorities responsible for supporting them in the new situation, also need overall assessments of various parameters of the business environment for innovation, and of factors limiting innovation activities.

The concept of business environment for innovation (innovation climate) is widely used in economic research, but in practice, obtaining relevant comprehensive (quantitative) assessments turns out to be a very difficult task. One of the few tools applied to measure such complex and multidimensional concepts is composite innovation indices (Vlasova, 2023); however, they provide only an aggregated assessment, which does not reflect busi-

nesses' consensual view of the current rules of the game and of the status quo.

The proposed approach to analysing the business community's sentiment regarding the conditions for innovation in Russia is based on the market research methodology (OECD, 2003), and the results of a specialised survey of high-tech manufacturing and service enterprises conducted by the HSE ISSEK in early 2022. The main objective is to assess Russian businesses' adaptive potential, their willingness to restructure and move on in the new economic realities.

Based on the classification of environmental factors affecting innovation development presented in the guidelines for collecting and interpreting innovation data (OECD, Eurostat, 2018), the Russian business community's satisfaction with the current conditions for innovation was assessed, and its expectations regarding the possible changes over the next three years structured. Particular attention was paid to the differences in attitudes and expectations, and in the perception of business environment faults between enterprises operating in different sectors of the economy (traditional high-tech manufacturing and service industries), which demonstrate different innovation behaviour patterns (engaged and not engaged in innovation and export activities). In particular, to take into account highly diverse requirements of various company types to possible government support measures (Roud, 2018; Vlasova, Roud, 2020), a typology of organisations was used, based on their experience of implementing innovations, participating in export activities, and conducting research and development (R&D).

The results obtained expand our understanding of the factors affecting businesses' adaptation to external constraints, and allowed to suggest some recommendations for Russian innovation policy. The survey did not cover the sanctions period itself, but firstly, it allowed to assess the initial state of affairs in the surveyed organisations, which is important for understanding their perception of the further developments. Secondly, the findings are likely to be relevant to the current circumstances, as supported by existing literature. Domestic businesses (especially those operating in high-tech sectors) have been facing serious external restrictions since 2014[1] and earlier, and during the pandemic crisis, when they had to find ways to overcome external shocks.

The first section of the paper presents a review of the literature on innovative businesses' diverse behavioural responses to exogenous challenges. The second one structures business environment factors affecting innovation, and substantiates the

---

[1] Certain sanctions have been imposed by foreign countries after 2014 too.

need to measure them to assess companies' adaptive potential. The third section describes the methodology and information basis of the study. The fourth presents the results of a comprehensive empirical assessment of the business environment parameters, including the faults noted by the Russian business community. The concluding section discusses the main findings, and presents public policy recommendations.

Companies' innovation strategies in the situation of exogenous shocks

In recent decades, businesses in Russia and other countries have regularly faced various crises which transformed the markets, affected innovation activities, organisations' performance, etc. Exogenous shocks suppress companies' motivation to innovate in a highly uncertain situation (Spatt, 2020), exacerbated by unavoidable resource constraints including reduced demand and income, decreased liquidity and availability of external financing (Huang, Lee, 2023). Compared to a growth period, in a turbulent situation the short-term returns from implementing innovations are lower, which encourages businesses to cut expenditures on relevant R&D (Mand, 2019).

At the same time, crisis periods play an important role in the emergence of new innovation paths. Having to operate in extreme conditions pushes companies to search for new growth strategies (Leduc, Sill, 2013). E.g. the 2008-2009 financial crisis became a catalyst for the digitalisation of financial services, prompting the development of efficient financial technologies based on big data, artificial intelligence, machine learning, and cloud services. Small innovative businesses, along with companies which have actively invested in innovation in the pre-crisis period, gained a growth momentum (Archibugi et al., 2013).

The most important characteristic of the crises caused by sanctions- and pandemic-related restrictions (despite their quite different reasons) was the emergence of numerous gaps in global value chains (Alcorta et al., 2021). Structural changes happen in various industries, and negatively affect not only obviously inefficient enterprises, but also competitive companies with high technological potential. E.g. due to the sanctions introduced in 2022, more than half of Russian manufacturing enterprises faced problems with logistics, product and service imports, and increased prices for raw and other materials and components (Simachev et al., 2023).

External shocks affected the mood of the business community in different ways, depending on various factors related both to the nature of the crisis itself, the national, industry, and organisational specifics, and the state anti-crisis policy. An analysis of the literature on innovation revealed researchers' high interest in studying the characteristics and conditions of the business environment which affect companies' sustainability during turbulent periods, and the choice of corporate adaptation strategies. Important factors include the firms' experience in creating innovations (Archibugi et al., 2013), participating in export activities (Jung et al., 2018), and their R&D potential (measured as R&D expenditures) (Mand, 2019). Despite the cyclical nature of such investments, during a crisis they can help strengthen companies' competitiveness. Other factors identified by researchers may also have a similar effect.

E.g. during the 2008 crisis, not only an increase in R&D expenditures in sectors such as pharmaceuticals, biotechnology, and chemical production was noted (Lech, 2011), but also grassroots growth of innovation activity: many companies created technological innovations, every third one introduced process innovations, and one in five invested in product innovation (Paunov, 2012). All other things being equal, low dependence on imports, and no participation in export activities can, to a certain extent, mitigate the negative impact of sanctions and other external challenges. On the other hand, innovative and export-oriented companies have a wider range of funding sources, and are less dependent on domestic demand, which frees up additional resources for building effective adaptation strategies and overcoming crisis-related limitations.

Russian business is going through a period of adapting to the new circumstances, searching for the best ways to respond to them. An assessment of corporate behavioural strategies in a situation of major changes shows that the initially neutral, and sometimes even positive perception of new challenges by top company management contributed to focusing on innovation, and market expansion (Simachev et al., 2023). The restrictions associated with the COVID-19 pandemic, and the 2022 sanctions pushed Russian businesses to expand their presence in traditional markets and enter new ones, develop promising niches for new products, etc. In particular, service organisations specialising in digital communications actively developed various remote employment formats, and vital online delivery services (Kuzminov, Serkov, 2020). Only about a third of Russian enterprises (mostly not engaged in innovation activities) did not make any effort to adapt either during the acute phase of the COVID-19 pandemic, or during the period of sanctions pressure. Statistical data for 2022[2] recorded a slight

---

[2] https://rosstat.gov.ru/statistics/science#, accessed on: 22.12.2023.

decrease in Russian organisations' innovation activity (11% versus 11.9% in 2021), while they have maintained their relevant expenditures at constant prices, and increased their rate (2.1% versus 2%). During the crisis businesses changed the focus from pursuing long-term strategic goals to dealing with basic operational objectives, but they continued to see innovation as a factor in maintaining and stepping up their operations.

The role of business environment in innovation development

Among the many prerequisites for corporate innovation, and the conditions for its productivity, business environment characteristics attract particular attention in the literature. They are listed in the Oslo Manual - guidelines for collecting and interpreting innovation data (OECD, Eurostat, 2018). While remaining beyond the control of company management, these factors significantly affect management decisions regarding the implementation of innovations. A productive environment for innovation is defined by geography (company location), market parameters, and knowledge dissemination and exchange mechanisms (human resources, availability of financial resources and infrastructure), specific features of government regulation, and the public sphere.

Stable demand for company products, and the possibility of market expansion (which determine potential profits) are among the key external factors of increasing corporate innovation expenditures, and more generally, of coming up with an "innovative response" to changing operating conditions (Paunov, 2012). In a situation of economic shock, business activity and consumer demand decline, which requires reviewing and restructuring competition and marketing strategies. E.g. during the pandemic, enterprises in various industries (in particular, pharmaceuticals) have significantly expanded their product lines and developed an online economy, increasing sales in existing markets and entering new ones (Huang, Lee, 2023). A no less important aspect is entering foreign markets. Diversification and international openness tend to increase returns on innovation, and open access to additional resources (Panwar et al., 2022).

The most important business environment characteristic is the level of competition. However, its connection with innovation activity is not very clear (Aghion et al., 2018; Negassi, Hung, 2014). Competition is a key incentive to search for new strategies and growth sources, among which technological or organisational innovations hold a special place (Camps, Marques, 2014; Baranov, Dolgopyatova, 2013). At the same time, too strong or too weak competition sometimes can suppress companies' innovation activity due to increased costs, market barriers, lack of incentives, etc.

Cooperation can contribute to strengthening competitive advantages during a recession, e.g. in the form of joint R&D, or digital interaction via marketplaces or digital platforms (D'Agostino, Moreno, 2018). Joining forces allows not only to reduce the risks and costs of implementing innovations, but also speed up their development. The decisive factors for stepping up cooperation during a crisis are macroeconomic dynamics, and financial stability of individual organisations and the industry as a whole.

Another important component of the innovation climate is infrastructure, which provides mutual benefits for players in the educational, scientific, industrial, and other sectors (Gorzelany-Dziadkowiec et al., 2019). Transport, energy, information and communication (including the internet), and social (housing, healthcare, education, etc.) infrastructure is a vital aspect of successful entrepreneurial activity, and of establishing links between key participants in the commercialisation of R&D results (Dezhina, Saltykov, 2004).

In addition to markets and infrastructure, another factor in businesses' rapid adaptation to new economic realities and stepping up innovation is access to resources - material (equipment, production space, raw and other materials, etc.), human (first of all highly skilled workers and professionals to support critical business processes), and financial ones. Although resources are controlled by management, the possibilities of attracting, accumulating, and distributing them largely depend on the economic situation and government policy.

The results of numerous studies confirm that during a crisis, companies' survival and innovation activities, including R&D, are positively correlated with the availability of public financial support in the form of grants and subsidies (Becker, 2015; Jung et al., 2018). Access to borrowed funds (bank loans, bond issues, leasing, export credit agencies' resources) and to venture financing significantly affect the resource potential of business organisations (Peia, Romelli, 2022).

The social context, including the public's interest, and level of confidence in new technologies, and S&T development generally, significantly affects business and innovation activity. Although as a rule, society tends to have a positive opinion of science and technology's contribution to the socio-economic progress (Naor et al., 2015), during crises this attitude often changes, and in different ways for different population groups. Since various kinds of recessions are becoming more and more unpredictable, and their consequences more difficult to manage with traditional anti-crisis measures, e.g. monetary ones, the distrust of economic agents, including individuals, in the entire government vertical and affiliated structures (consulting, informational, expert, intermediary agencies), the

Table 1. **Sample Structure**		
Parameters	**Number of organisations in the sample**	**Number of organisations in weighted sample**
Organisation size		
Small (< 50 employees)	724	10 688
Medium (51–250)	280	2666
Large (> 250)	116	669
Economy sector		
High-technology manufacturing industries	486	3088
Services	635	10 945
Organisation type		
Non-innovative	286	2 411
Innovative, non-exporting	632	8048
Innovative, exporting	203	3574
Innovative, conducted R&D	820	10 396
Total	1121	14 033
Source: authors.		

state, government institutions in general, their actions and decisions is growing. The level of openness to new technologies and innovations, and people's attitude towards them are directly related to the latter's standard of living and education, the perception of technological innovations' capabilities and ease of use, usefulness, and reliability (Pishnyak, Halina, 2021). The public sector's demand for innovation also plays an important role (Patanakul, Pinto, 2014).

Last but not least important business climate component is government regulation and administrative barriers. The country's economic policy as a whole, and its specific elements including tax and customs legislation, the quality of the judicial system, and the activities of control and supervisory authorities largely determine businesses' innovation behaviour patterns (Pakhomova et al., 2015). The intellectual property protection regime also plays a special role. As foreign experience shows, in industries with a high patent activity companies tend to be less sensitive to exogenous shocks, so during recessions they continue to implement their pre-crisis strategy and do not step down innovation activity (Archibugi et al., 2013; Fabrisio, Tsolmon, 2014). With insufficient level of intellectual property protection, copying and imitation proliferate, while an adequate protection guarantees companies income from inventions and innovations, i.e. financial stability, including in a turbulent external environment.

Thus, the results of numerous studies indicate that the environment in which companies operate is one of the most important factors in their innovation development. It sets the rules of the game, defines the opportunities for, and barriers to adapting the business to changes in its operating conditions.

Methodology and data

The analysis conducted in the scope of the study is based on the results of a specialised survey of innovation behaviour of Russian enterprises conducted in January-March, 2022 by the National Research University Higher School of Economics Institute for Statistical Studies and Economics of Knowledge. The methodological basis of the survey was market research, which allowed, through structured interviews, to reveal managers' attitudes and expectations regarding the current situation in their organisations, and their plans for the next three-year period. The empirical basis of the analysis was data on 1,121 enterprises operating in high-tech manufacturing industries (OKVED 20, 21, 26, 30) and the service sector (OKVED 61, 62, 63)[3] employing more than 10 workers.

The sectoral structure of the sample is due to the fact that the selected sectors of the Russian economy have a high level of innovation activity: in 2021, 17.4% in manufacturing, 44.5% in traditional high-tech industries (pharmaceuticals, electronics, chemical products, vehicles), and 10.5% in services. The sample is stratified, and representative in terms of the criteria applied to normalise it for empirical analysis, taking into account the actual parameters of the Russian economy (Ruslana Bureau Van Dijk data was also used).[4] The general structure of the sample is presented in Table. 1. The survey tool was harmonised with the international standard for measuring innovation activity, and in addition to questions about the framework conditions for it, included questions on new product and/or business process development by companies over the previous three years (innovation activity), R&D expenditures, and export operations.

Based on the identified characteristics of the respondent companies, a typology was developed, which allowed to assess their adaptation potential on the basis of their innovation behaviour patterns. The following organisation types were considered in the course of the empirical analysis: 1) non-innovative companies (have not introduced any new products over the previous three years); 2) innovative, but not engaged in export activities (in 2021); 3) innovative and exporting firms; and 4) innova-

---

[3] OKVED codes: 20 - Production of chemical substances and chemical products; 21 - Production of medicines and materials used for medical purposes; 26 - Production of computers, electronic and optical products; 30 - Production of other vehicles and equipment; 61 – Telecommunication-related activities; 62 - Computer software development, consulting services in this area, and related services; 63 - Information technology-related activities.

[4] https://www.bvdinfo.com/, accessed on 11.04.2022.

Table 2. **Business environment factors affecting companies' innovation activities**		
Factor groups	**Number of factors**	**Description**
Markets	5	Stable demand for company's products, opportunities to enter new markets and expand presence in the current ones
Competitive environment	6	Stability of competitive advantages, factors in obtaining and retaining them, cooperation opportunities
Materials and equipment	4	Material production factors: floor space, access to raw materials, supplies, and equipment, including imported ones
Human resources	6	Availability of workers specialising in various business processes (production, administration, marketing and sales, logistics, new product development, etc.)
Financial resources	7	Availability of own resources, and access to external funding sources (credits, loans, leasing, venture investments, government support)
Infrastructure	6	Quality of infrastructure (transport, energy, social, information and communication, etc.)
Government regulation	9	Economic policy and its specific elements (tax and customs regulation, judicial system quality, intellectual property protection, etc.)
Social environment	4	The level of trust between partners, businesses and the state; the public's interest in new technologies; public sector's demand for innovation
Source: authors.		

tive companies which have conducted R&D (incurred expenditures on R&D conducted in-house and/or jointly with third-party organisations in 2021). This classification allowed to identify barriers and faults which hinder stepping up innovation, depending on Russian businesses' level of maturity.

The respondents assessed the conditions for their companies' innovation development using a set of 47 factors broken down into 8 groups: markets, competitive environment, material, human, and financial resources, quality of infrastructure, government regulation, and social environment. Business environment parameters were selected taking into account exogenous factors of innovation activities included in the latest edition of the Oslo Manual (OECD, Eurostat, 2018), and on the basis of a review of relevant scientific literature. Their brief description is presented in Table 2.

Company managers assessed each factor's current state, and expected dynamics over a three-year horizon using a Likert scale, where 1 meant negative assessment of the current situation / expected deterioration, and 5 positive assessment / expected improvement. Based on the survey results, specific factors' and factor groups' indices were calculated (the average value for factors with equal weight) as part of assessing the overall business environment for innovation, and a composite sentiment and expectations index (average values for factor groups).

At the first stage, we analysed how the Russian business community assessed the current situation for innovation activities, and the prospects for the next three years - in general, by factor groups, and by individual factors. At the second stage, business environment faults were identified: potential barriers hindering the stepping up of innovation. The statistical significance of the differences in barriers' assessment by companies displaying different

innovation behaviour patterns was measured using one-way analysis of variance (ANOVA) (Rueda, 2023). The statistical significance of differences in median cluster values was measured using the Kruskal-Wallis test. Non-overlapping sets of organisations were considered, depending on their involvement in innovation and export activities. The analysis was carried out for all types of economic activities under consideration generally, and at the industry level (traditional high-tech and service industries).

Analysis results

Business environment for innovation: business community's sentiment and expectations

At the beginning of 2022, the Russian business community assessed the conditions for creating innovations moderately positively: the sentiment index was 3.47 out of 5 (Table 3). Since the survey coincided with the beginning of the imposition of systemic sanctions against Russia by Western countries, company managers predictably did not expect the situation to improve over the next three years (with some minor exceptions for certain factor groups). However, there were no radically decreased assessments either. This applies both for high-tech manufacturing, and service sector companies.

According to the respondents, in the current realities, the barriers associated with government regulation (3.19) and availability of financial resources (3.25) hinder innovation development most significantly. As to specific factors, in the financial resources group companies faced (and will likely continue to face) the biggest problems with attracting external funding, especially from export credit agencies, bond issues, and venture investors. Busi-

Factor group	Traditional high-tech		Services		Total	
	Current	Expectations	Current	Expectations	Current	Expectations
Markets	3.52	3.46	3.41	3.38	3.44	3.40
Competitive environment	3.58	3.56	3.53	3.57	3.54	3.57
Materials and equipment	3.63	3.38	3.55	3.29	3.57	3.31
Human resources	4.05	3.83	3.75	3.65	3.82	3.69
Financial resources	3.41	3.36	3.20	3.29	3.25	3.31
Infrastructure	3.86	3.61	3.65	3.43	3.70	3.47
Government regulation	3.27	3.25	3.17	3.11	3.19	3.14
Social environment	3.70	3.68	3.52	3.55	3.56	3.58
Composite index	**3.60**	**3.49**	**3.44**	**3.38**	**3.47**	**3.40**

Table 3. Sentiment and expectations indices by business environment factor group and economic activity type

Note: the composite index provides a generalised assessment of the conditions for innovation activities, and the prospects for their change as perceived by company managers. It was assessed using 47 factors broken down into 8 groups, calculated as their arithmetic mean. Each factor was measured using a five-point scale with 1 meaning negative assessment of the current situation / expected deterioration in three years' time, 5 positive assessment / expected improvement, and 3 neutral assessment / no change..

Source: authors.

nesses are concerned about the quality of the judicial system and the activities of control and supervisory authorities, and, for obvious reasons, major issues with entering foreign markets.

Factor groups related to human resources and infrastructure quality received the highest scores (3.82 and 3.70, respectively), for both current state and expectations. As with a number of other business environment aspects, a slight deterioration is possible for both these groups in the next three years (–0.13 and –0.23, respectively). Regarding business processes, the respondents were most pessimistic about the availability of personnel for product development, including R&D and production/provision of services. In terms of infrastructure, the respondents positively assessed factors related to communications and the internet, and relatively negatively the availability of social infrastructure: housing, medical services, schools and kindergartens, recreation areas, the quality and costs of waste disposal services.

Analysis of business sentiment taking into account innovation behaviour patterns revealed that companies with actual innovation experience generally assessed the relevant conditions more positively (Table 4).

Non-innovative companies were more pessimistic about the current situation (for high-tech manufacturing enterprises, this indicator value was 3.40, and for service ones 3.21). Unsatisfactory scores (<3) also received certain factor groups in the service sector. As noted in a number of previous studies (see, e.g., Roud, 2018), this suggests that in the absence of actual experience of applying innovations, business environment characteristics become a major factor in making decisions about launching new innovative projects.
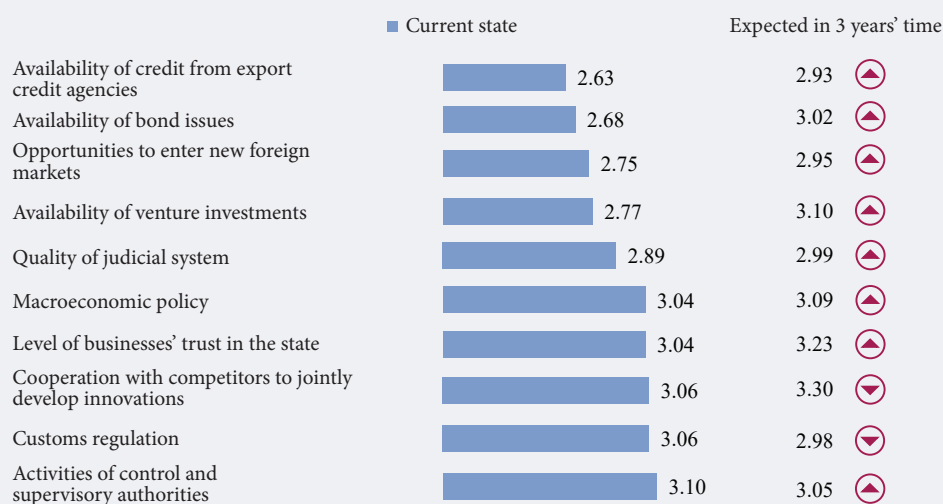
Innovative service companies engaged in export activities assessed the conditions for innovation development moderately positively (3.58). Such companies' managers also demonstrated a relatively high level of satisfaction with the market situa-

Table 4. Sentiment indices by business environment factor group and innovation behaviour pattern

Factor group	Non-innovative		Innovative, non-exporting		Innovative, exporting		Innovative, conducting R&D	
	Hi-tech	Services	Hi-tech	Services	Hi-tech	Services	Hi-tech	Services
Markets	3.07	2.86	3.51	3.42	3.74	3.81	3.65	3.57
Competitive environment	3.33	3.16	3.71	3.59	3.53	3.65	3.65	3.62
Materials and equipment	3.51	3.30	3.69	3.61	3.61	3.61	3.65	3.60
Human resources	3.89	3.69	4.16	3.77	3.97	3.75	4.10	3.77
Financial resources	3.10	2.92	3.57	3.23	3.35	3.33	3.47	3.27
Infrastructure	3.74	3.47	3.90	3.67	3.87	3.74	3.86	3.67
Government regulation	3.10	2.99	3.39	3.11	3.18	3.22	3.29	3.15
Social environment	3.43	3.29	3.88	3.58	3.58	3.53	3.78	3.59
Composite index	**3.40**	**3.21**	**3.73**	**3.50**	**3.60**	**3.58**	**3.68**	**3.53**

Source: authors.

Figure 1. **Factors with the lowest scores in 2022, and expectations regarding their changes**

	Current state	Expected in 3 years' time
Availability of credit from export credit agencies	2.63	2.93 ▲
Availability of bond issues	2.68	3.02 ▲
Opportunities to enter new foreign markets	2.75	2.95 ▲
Availability of venture investments	2.77	3.10 ▲
Quality of judicial system	2.89	2.99 ▲
Macroeconomic policy	3.04	3.09 ▲
Level of businesses' trust in the state	3.04	3.23 ▲
Cooperation with competitors to jointly develop innovations	3.06	3.30 ▼
Customs regulation	3.06	2.98 ▼
Activities of control and supervisory authorities	3.10	3.05 ▲

Source: authors.

tion (3.81), in particular stability of demand, opportunities to step up sales and enter new markets, and consumers' willingness to pay more for technologically improved products and services.

On the contrary, in the high-tech manufacturing segment, innovative companies operating exclusively in the Russian market assessed the business environment higher (3.73), along with the firms investing in R&D (3.68). The respondents in this group noted a relatively favourable situation with the availability of human resources and infrastructure, trust in business partners and in the state, and the public sector's demand for innovations.

Business environment faults hindering innovation development

Against the background of moderately positive assessments (overall ones, of the current situation, and expectations for the next three years), the respondents were quite worried about certain aspects (see Fig. 1), first of all limited access to external financing. Business environment characteristics related to sources of borrowed capital were also assessed as unsatisfactory, namely the availability of resources from export credit agencies (2.63), bond issues (2.68), and venture investments (2.77). Despite a satisfactory assessment of own financial potential (3.77), the business community expected the situation to deteriorate here too (–0.12). Thus the already not very favourable state of affairs with financial support for innovation activities is becoming increasingly uncertain.

Companies expect problems with entering foreign markets (2.75), given the growing sanctions pressure, the latter are unlikely to become more available in the near future. The respondents were

equally pessimistic about the possibilities to cooperate with competitors to conduct R&D and develop innovations (3.06), though under normal circumstances such cooperation makes a decisive contribution to the productivity of relevant activities. The inadequate framework conditions for innovation, and less-than-perfect government regulation also significantly weaken Russia's innovation potential. Apart from the distrust in the actions of the state (3.04), and the concerns about the overall macroeconomic policy (3.04), the respondents noted the weak judicial system (2.89), ineffective tax (3.15) and customs (3.06) mechanisms, inadequate activities of control and supervisory authorities (3.10), and insufficient anti-crisis support during the pandemic (3.12).

The perception of bottlenecks hindering the increase in innovation activity is not clearly differentiated by sector, but varies considerably depending on companies' behaviour patterns. The ANOVA analysis and the Kruskal-Wallis test revealed statistically significant (at 1%) differences between the average values, both for the current state and expectations, of almost all negative factors of the business environment (Table 5). The only exception is quality of judicial system, which the respondents, regardless of their involvement in innovation and export activities, considered to be one of the weakest points of the Russian innovation system.

Innovative companies engaged in export activities were less critical in assessing existing barriers, while managers of non-exporting companies turned out to be more optimistic about their expectations for the next three years. Apparently, having a good position in the domestic market (own niche, stable demand, etc.) gives innovative companies confidence in the future even if economic conditions change.

Table 5. **Assessment of business environment factors by organisation type (ANOVA results)**				
Factor	**Organisation type**	**Number of observations**	**Average assessment of current state/expectations**	**Standard deviation**
Availability of credit from export credit agencies	Innovative, exporting	2019	3.01/2.92	1.15/1.05
	Innovative, non-exporting	3736	2.59/3.02	1.05/1.13
	Non-innovative	1487	2.20/2.71	1.09/0.97
	ANOVA		***	
Availability of bond issues	Innovative, exporting	2175	2.90/2.95	1.17/1.01
	Innovative, non-exporting	4066	2.68/3.11	1.00/1.01
	Non-innovative	1606	2.41/2.88	1.02/0.95
	ANOVA		***	
Opportunities to enter new foreign markets	Innovative, exporting	3270	3.49/3.40	1.24/1.23
	Innovative, non-exporting	5379	2.56/2.82	1.32/1.12
	Non-innovative	1830	1.99/2.57	1.14/1.09
	ANOVA		***	
Availability of venture investments	Innovative, exporting	2195	3.10/3.12	1.13/1.11
	Innovative, non-exporting	3981	2.75/3.19	0.93/1.06
	Non-innovative	1531	2.37/2.79	1.04/0.98
	ANOVA		***	
Quality of judicial system	Innovative, exporting	2788	2.87/3.00	1.08/1.01
	Innovative, non-exporting	6439	2.90/2.99	0.99/0.92
	Non-innovative	1945	2.86/3.00	1.06/1.01
	ANOVA			
Cooperation with competitors to jointly develop innovations	Innovative, exporting	3168	3.03/3.37	1.23/0.93
	Innovative, non-exporting	6432	3.18/3.33	1.06/0.91
	Non-innovative	2038	2.70/3.08	1.01/0.89
	ANOVA		***	
Macroeconomic policy	Innovative, exporting	3154	3.04/3.06	1.14/1.20
	Innovative, non-exporting	6879	3.11/3.19	1.06/1.10
	Non-innovative	2029	2.79/2.76	1.03/1.10
	ANOVA		***	
Activities of control and supervisory authorities	Innovative, exporting	3177	3.20/3.21	1.03/1.04
	Innovative, non-exporting	7337	3.10/3.00	0.97/0.97
	Non-innovative	2142	2.96/2.94	0.99/1.00
	ANOVA		***	
Customs regulation	Innovative, exporting	2709	3.18/3.03	1.05/1.06
	Innovative, non-exporting	4950	3.00/2.97	0.79/0.91
	Non-innovative	1662	3.05/2.91	0.84/0.97
	ANOVA		***	
Level of businesses' trust in the state	Innovative, exporting	3305	2.96/3.21	1.18/0.99
	Innovative, non-exporting	7455	3.16/3.32	1.17/1.15
	Non-innovative	2209	2.72/2.94	1.11/1.05
	ANOVA		***	

Note: ***, **, * indicate significance at the level of 10%, 5%, and 1%, respectively. The median value for all factors is 3.00. The results of group comparison using the Kruskal-Wallis test are available upon request.
Source: authors.

Conclusions and discussion

Analysis of the business community's sentiments and expectations regarding the changes in the framework conditions for innovation allowed to assess Russian businesses' willingness to develop innovations against the background of unfavourable external and internal conditions.

A unique database was created, on the basis of which the characteristics of the innovation climate were examined, and key barriers to its improvement structured at the level of companies operating in various industries (in our case, high-tech manufacturing and service sectors), and displaying various behaviour patterns (engaged in innovation and export activities, conducting R&D). Though the survey to collect data for the study was conducted before the imposition of major sanctions restrictions, its results are still applicable for assessing the innovation dynamics and adjusting relevant government policy initiatives. In particular, the findings indicate that managers of Russian companies see potential for improving the innovation climate (at the beginning of 2022, the composite sentiment index in both traditional high-tech and service sectors was at about 3.5 out of 5). However, even before the exacerbation of crisis trends, the surveyed managers did not expect significant improvements over a three-year horizon, among other reasons due to the business environment faults they constantly face in their operations.

The survey results also confirm that in the context of a turbulent external environment, and significant delays in the publication of official statistical observation data, regular collection of information about business community's mood remains relevant. It facilitates feedback between authorities and society, and expands the empirical basis for innovation (and innovation policy) research. The obtained estimates confirm the results of previous studies (Archibugi et al., 2013; Jung et al., 2018), and reveal fundamental differences in the perception of conditions for innovation development by companies which display different innovation behaviour patterns. Organisations not engaged in these activities rate almost all business environment aspects as unsatisfactory (<3). Meanwhile innovative firms which export their products or conduct R&D (especially in high-tech industries) generally tend to be more optimistic in assessing both the status quo, and future prospects (between 3.50 and 3.73).

The business community believes the key factors of achieving stable growth and successfully adapting to external turbulence are the availability of human resources and high-quality infrastructure, first of all information, communications and energy ones. In turn, the public's interest in new technologies and innovations allows to expect high consumer demand for products and services even in times of crisis.

According to the respondents, the rate of adapting to new economic realities may be negatively affected by issues with attracting financing (both borrowed capital, and public funding), limited access to foreign markets, and less-than-perfect public institutions and regulatory system. The level of direct government participation in the domestic economy, which during periods of turbulence increases even further, is constantly criticised. According to some experts, under the sanctions pressure authorities are likely to rely on the project model and targeted financing of public sector organisations, including large state-owned companies. As a result, both the timeframe for making management decisions at all levels, and the costs of their implementation may increase, while the expected effects, on the contrary, may become less significant.[5]

The study demonstrated that the business community is much more interested in altering the government's role from direct participation in business activities to that of a regulator, who, among other things, would strive to improve the business environment. A quick resolution of a number of systemic issues which determine the rules of the game in the business sector would promote market competition, and create more favourable conditions for stepping up innovation activity.

Companies' perception of key business environment faults also significantly differs depending on the level of their involvement in innovation and export activities. For innovative organisations integrated into global value chains, the key barriers are related to the shrinking opportunities for cooperation with competitors in conducting R&D (which is particularly important for high-tech enterprises), and a relatively low level of trust in authorities' actions. Innovative companies' exports are mainly hindered by inadequate customs regulation, and problems with attracting external financing (export credit organisations' resources, bond issues, venture investments). In addition to financial constraints, innovation is also hampered by top management's negative perception of the opportunities for entering new, especially foreign, markets.

The identified diversity in assessments of the faults of the business environment for innovation, associated with companies' behaviour patterns, provides an empirical basis for developing initiatives to support business during periods of economic instability. Eliminating major faults of this kind may accelerate the real sector's adaptation to innovation development in the situation of external restrictions.

---

[5] https://kiozk.ru/article/ekspert/30-let-russkih-innovacij-pocemu-ne-slozilsa-pazl; https://stimul.online/articles/interview/vyyti-s-tekhnologicheskoy-po-luperiferii/; https://stimul.online/articles/sreda/nuzhna-dostroyka-innovatsionnoy-sistemy/, accessed on 14.08.2023.

References

Aghion P., Bechtold S., Cassar L., Herz H. (2018) The causal effects of competition on innovation: Experimental evidence. *Journal of Law, Economics, and Organization*, 34 (2), 162–195. https://doi.org/10.1093/jleo/ewy004

Alcorta A., Porta A., Tárrega A., Dolores Alvarez M., Pilar Vaquero M. (2021) Foods for plant-based diets: Challenges and innovations. *Foods*, 10(2), 293. https://doi.org/10.3390%2Ffoods10020293

Archibugi D., Filippetti A., Frenz M. (2013) Economic crisis and innovation: Is destruction prevailing over accumulation? *Research Policy*, 42 (2), 303–314. https://doi.org/10.1016/j.respol.2012.07.002

Baier E., Zenker A. (2020) Regional autonomy and innovation policy. In: *Regions and Innovation Policies in Europe. Learning from the Margins* (eds. M. González-López, B.T. Asheim), Cheltenham: Edward Elgar Publishing Limited, pp. 66–91.

Baranov A.Y., Dolgopyatova T.G. (2013) *Empirical analysis of innovative behavior of firms under different institutional conditions*, Moscow: HSE University (in Russian).

Becker B. (2015) Public R&D policies and private R&D investment: A survey of the empirical evidence. *Journal of Economic Surveys*, 29 (5), 917–942. https://doi.org/10.1111/joes.12074

Brancati E., Brancati R., Maresca A. (2017) Global value chains, innovation and performance: Firm-level evidence from the Great Recession. *Journal of Economic Geography*, 17 (5), 1039–1073. https://doi.org/10.1093/jeg/lbx003

Camps S., Marques P. (2014) Exploring how social capital facilitates innovation: The role of innovation enablers. *Technological Forecasting and Social Change*, 88, 325–348. https://doi.org/10.1016/j.techfore.2013.10.008

D'Agostino L.M., Moreno R. (2018) Exploration during turbulent times: An analysis of the relation between cooperation in innovation activities and radical innovation performance during the economic crisis. *Industrial and Corporate Change*, 27 (2), 387–412. https://doi.org/10.1093/icc/dtx035

Dezhina I.G., Saltykov B.G. (2004) *Mechanisms of stimulation of commercialization of research and development*, Moscow: Gaidar Institute of Economic Policy (in Russian).

Fabrizio K.R., Tsolmon U. (2014) An empirical examination of the procyclicality of R&D investment and innovation. *Review of Economics and Statistics,* 96 (4), 662–675. https://www.jstor.org/stable/43554947

Gorzelany-Dziadkowiec M., Gorzelany J., Stauskis G., Hernik J., Van Assche K., Noszczyk T. (2019) The innovation process in local development–the material, institutional, and intellectual infrastructure shaping and shaped by innovation. *Technological and Economic Development of Economy*, 25 (6), 1232–1258. https://doi.org/10.3846/tede.2019.11094

Huang H.Y., Lee Y.C. (2023) Modern pandemic crises and R&D investment. *Applied Economics*, 1–14. https://search.bvsalud.org/global-literature-on-novel-coronavirus-2019-ncov/resource/en/covidwho-2323682, accessed 15.02.2024.

Jung H., Hwang J.T., Kim B.K. (2018) Does R&D investment increase SME survival during a recession? *Technological Forecasting and Social Change*, 137, 190–198. https://doi.org/10.1016/j.techfore.2018.07.042

Kuzminov A.V., Serkov L.N. (2020) Innovations in the market of telecommunication services. In: *Conference Proceedings 'Economics: management, finance in the XXI century: The view of the modern scientific world', 26.12.2020, Kazan, Russia*, pp. 151–159 (in Russian).

Lech A. (2011) Research and Development Expenditures of Innovative Enterprises in the Time of Crisis. *Comparative Economic Research. Central and Eastern Europe*, 14 (3), 71–86. https://doi.org/10.2478/v10103-011-0019-x%0A

Leduc S., Sill K. (2013) Expectations and economic fluctuations: An analysis using survey data. *Review of Economics and Statistics,* 95(4), 1352–1367. https://www.jstor.org/stable/43554832

Mand M. (2019) On the cyclicality of R&D activities. *Journal of Macroeconomics*, 59, 38–58. https://doi.org/10.1016/j.jmacro.2018.10.008

Naor M., Bernardes E.S., Druehl C.T., Shiftan Y. (2015) Overcoming barriers to adoption of environmentally-friendly innovations through design and strategy: Learning from the failure of an electric vehicle infrastructure firm. *International Journal of Operations & Production Management*, 35(1), 26–59. https://doi.org/10.1108/IJOPM-06-2012-0220

Negassi S., Hung T.Y. (2014) The nature of market competition and innovation: Does competition improve innovation output? *Economics of Innovation and New Technology*, 23(1), 63–91. https://doi.org/10.1080/10438599.2013.811936

OECD (2003) *Business Tendency Surveys: A Handbook*, Paris: OECD.

OECD, Eurostat (2018) *Oslo Manual 2018: Guidelines for Collecting, Reporting and Using Data on Innovation* (4th ed.), Paris: OECD, Eurostat.

Pakhomova N.V., Knuth R., Malyshkov G.B., Bondarenko Y.P. (2015) Stimulating Demand for Innovation: Institutional and Organizational Drivers. *St. Petersburg University Journal of Economic Studies*, 2, 4–33.

Panwar R., Pinkse J., De Marchi V. (2022) The future of global supply chains in a post-COVID-19 world. *California Management Review*, 64 (2), 5–23. https://doi.org/10.1177/00081256211073355

Patanakul P., Pinto J.K. (2014) Examining the roles of government policy on innovation. *Journal of High Technology Management Research*, 25 (2), 97–107. https://doi.org/10.1016/j.hitech.2014.07.003

Paunov C. (2012) The global crisis and firms' investments in innovation. *Research Policy*, 41 (1), 24–35. https://doi.org/10.1016/j.respol.2011.07.007

Peia O., Romelli D. (2022) Did financial frictions stifle R&D investment in Europe during the great recession? *Journal of International Money and Finance*, 120, 102263. https://doi.org/10.1016/j.jimonfin.2020.102263

Pishnyak A., Khalina N. (2021) Perception of New Technologies: Constructing an Innovation Openness Index. *Foresight and STI Governance*, 15(1), 39–54. http://doi.org/10.17323/2500-2597.2021.1.39.54

Roud V. (2018) Understanding the heterogeneity of innovation modes: Performance effects, barriers, and demand for state support. *Technological Forecasting and Social Change*, 133, 238–253. https://doi.org/10.1016/j.techfore.2018.04.025

Rueda A.P.M. (2023) Analysis of variance: ANOVA. In: *Handbook for Designing and Conducting Clinical and Translational Research, Translational Sports Medicine* (eds. A.E.M. Eltorai, J.A. Bakal, S.F. DeFroda, B.D. Owens), Amsterdam: Elsevier, pp. 157-160. https://doi.org/10.1016/B978-0-323-91259-4.00099-0

Simachev Y.V., Yakovlev A.A., Golikova V.V., Gorodny N.A., Kuznetsov B.V., Kuzyk M.G., Fedyunina A.A. (2023) *Adaptation of Russian industrial companies to sanctions: First steps and expectations*, Moscow: HSE University.

Spatt C.S. (2020) A tale of two crises: The 2008 mortgage meltdown and the 2020 COVID-19 crisis. *Review of Asset Pricing Studies*, 10(4), 759–790. https://doi.org/10.1093/rapstu/raaa019

Vlasova V., Roud V. (2020) Cooperative Strategies in the Age of Open Innovation: Choice of Partners, Geography and Duration. *Foresight and STI Governance*, 14 (4), 80–94. http://doi.org/10.17323/2500-2597.2020.4.80.94

Vlasova V.V. (2023) What Global Composite Indexes Can Tell about Innovation Climate in Russia. *Public Administration Issues*, 3, 155–180. http://doi.org/10.17323/1999-5431-2023-0-3-155-180 (in Russian).

Intrapreneurship as a Driver of Business Innovation

Vijay Vivek

Assistant Professor, achvivekvijay@gmail.com

G.R. Damodaran Academy of Management, Coimbatore, Tamil Nadu, India

Kumar Chandrasekhar

Assistant Professor, chandrasekark@alagappauniversity.ac.in

Alagappa University, Karaikudi, Sivaganga – 630003, Tamil Nadu, India

Abstract

The need for constant renewal with new capabilities and valuable assets in an increasingly complex context represents an extraordinary challenge for companies. One of the most relevant sources is hidden internal resources in the form of the entrepreneurial initiatives of personnel - intrapreneurship. Interest in this new type of entrepreneurship has been growing steadily over the last decade. This article contributes to the understanding of the factors influencing its development using the example of manufacturing enterprises in the most developed states of India. The role of key prerequisites such as individual entrepreneurial ability and acquired competencies (strategic thinking and proactive behavior) as well as the art of cultivating a unique innovation-friendly climate is revealed. The author's findings strengthen the case for new formats of economic development in addition to classical entrepreneurship. These findings may be useful for decision-makers deciding how to renew and build competitive advantage in a dynamic business environment.

Introduction

Entrepreneurship plays an important role in the transition of the economy to new technological structures and ensures job growth (Parker, 2011; Gawke et al., 2019), improves the overall economic situation (Yang et al., 2009). Finding new business models in today's increasingly complex context requires a strong ability to balance multiple factors with multidirectional influences and higher level competencies (Mom et al., 2015). One of the new strategies is intrapreneurship-internal entrepreneurship in which innovations are generated and the company is constantly updated. Intrapreneurship is a type of entrepreneurship in which new enterprises are created by employees and are part of the parent company (Antoncic, Hisrich, 2003). If in traditional entrepreneurship, the founder of the company, as an independent entity, assumes all the risks associated with its survival and development, then the intrapreneur receives full support from the employer, including covering risks (Bosma et al., 2013; Klofsten et al., 2021; Kuratko, Audretsch, 2013). Interest in such a business development mechanism from academic researchers is growing steadily (Hornsby et al., 2013).

Intrapreneurship can be seen as a safe space that allows the cultivation of new business projects for the constant renewal and sustainability of the company. The creation of such a space is a complex problem, since high-order management competencies are required. Work climate is often perceived as an objective characteristic of an organization. However, it is largely determined tacit hard-to-access knowledge due to the fact that it is a strategic competitive advantage.

Among the unique components of the creative process is the provision of certain free time within the work schedule for entrepreneurially oriented personnel to implement such projects. Absence strict framework requiring compliance with the official content of job functions gives employees the opportunity launch new ventures, motivates to experiment with new ideas (Menzel et al., 2007). This combination of free-spiritedness and commitment to the organization is a basic element of a unique corporate philosophy (Bolino et al., 2003; Schneider, Bowen, 1993). The factors that determine the development of intrapreneurship have not yet received sufficient coverage in research. The purpose of our article is to fill this gap. Our goal is to study the relationship between entrepreneurial competencies and the development of intrapreneurship, and to assess the contribution of the working climate in manufacturing companies to this process.

The article begins with a literature review of the theoretical foundations of intrapreneurship and its practices in the global and Indian contexts. It then reveals the regularities and conditions of its development or blocking, illustrated by the author's empirical research based on a survey of employees of leading industrial companies in India. The conclusion summarizes the key findings and substantiates their significance for cultivating new formats of innovative development.

Literature review

The phenomenon of intrapreneurship has been discussed in academic literature since the mid-1980s. (Pinchot, 1985; Drucker, 1986; Pinchot, Pellman, 1999). At the start of the development of this research area (1985–2007), mainly narrow specialists showed interest in it. The turning point came in 2008, as the global financial crisis prompted a rethinking of business models and the search for new renewal strategies. In this context, the considered format of entrepreneurship began to be perceived as an attractive and reliable alternative to risky endeavors. As a result, experts from different fields began to be involved in the study of the phenomenon under consideration (Valencia et al., 2016). Intrapreneurship is seen as one of the key mechanisms for generating the innovations that companies need to achieve sustainability in dynamic markets. The annual increase in the number of works on this topic has become exponential and reached its maximum in 2020. Thus, despite its relatively young age, intrapreneurship research has already "overgrown" with many publications (Hernández-Perlines et al., 2022). In the process of development, intrapreneurship acquired synonymous terms that, although they had a connection with corporate entrepreneurship, nevertheless had different connotations. Some researchers differentiate between corporate entrepreneurship, entrepreneurial orientation and intrapreneurship, the latter from an individual perspective (Amo, 2010). Entrepreneurial orientation, as one of the aspects of entrepreneurship, is disclosed in the works of (Wahyudi et al., 2021a, 2021b). Intrapreneurship involves several players, whose roles depend on different characteristics and backgrounds and personality traits (Mudambi et al., 2007; Reuber et al., 2018). Entrepreneurship involves seeking emerging opportunities and creating new economic value to enhance competitiveness (Drucker, 1986; Pinchot, 1985).

Various classifications are proposed, both of the types of intrapreneurship themselves and of the areas of its research. For example, (Blanca, 2018) identifies five research areas in terms of their focus: individuals, organizations, context, factors and outcomes. In turn, the authors of the study (Gawke et al., 2017) identified three types of intrapreneurship. The first relates to entrepreneurial orientation and is a higher order factor in which employees take initiative, develop innovations, share risks (Felício et al., 2012; Rigtering, Weitzel, 2013; De Jong et al., 2013; Valsania et al., 2013; Valsania et al., 2012). The second focuses on results, analyzing the contribution of staff to the company's development (Hornsby et al., 2009, Matthews et al., 2009, Bager et al., 2010; Camelo-Ordaz et al., 2011; Urbano,Turró, 2013; Belousova, Gailly, 2013). The third focuses on employee behavior that fosters a culture of intrapreneurship. It synthesizes concepts of entrepreneurial behavior (Edquist et al., 2001; Park et al., 2014) and strategic renewal of companies in response to external and internal changes (Zampetakis et al., 2009; Mustafa et al.,

2016; Gawke et al., 2017; Woo, 2018). It is this type that looks most promising in terms of the development of intrapreneurship research.

The potential of intrapreneurship is determined by two interrelated groups of factors (Antoncic, Hisrich, 2000). The first of these relates to the external environment and includes: dynamism, technological base, industrial growth rates and demand for new products.

Regarding the second, concerning intra-corporate aspects, the following are highlighted: freedom and reward (De Villiers-Schipers, 2012; Galván-Vela, Sánchez-Limón, 2017), social norms and character traits of employees (Ajzen, 1991, Neessen et al., 2019), job design (Bakker, Demerouti, 2014), proactive behavior (Parker et al., 2010), openness to new ideas, creativity, tolerance for mistakes and innovativeness (Santos-Vijande et al., 2022). When creating new business projects, there is a requirement that they be consistent with the main profile of the company. Despite the fact that intrapreneurship in general is considered more secure and prosperous compared to classical entrepreneurship (Buekens, 2014), the internal corporate environment has an ambiguous influence on it. In some cases, it can become a limiting factor, for example, if the company is unreceptive to new development formats and has a strict internal bureaucracy.

The success or failure of intrapreneurship projects largely depends on having a holistic vision and sensitivity to complex dynamics (De Keyser, Vandenbempt, 2023; Glinyanova et al., 2021), which requires a combination of difficult-to-combine contradictions in at least four directions: altruism with personal interests, freedom of action with subordination, theory with practice, openness with personal boundaries. But the most significant abilities in this regard relate to the search for new opportunities.

Search for new opportunities

In the context of intrapreneurship, the focus is on identifying opportunities (Neessen et al., 2019) and their different combinations. Opportunities do not arise randomly and in isolation, but appear as a result of the acquisition of high competencies, efforts, consistency in actions, adjustments in strategy, etc. Different types of opportunities are revealed by corresponding management approaches (Verbecke, Yuan, 2022). Within the framework of intrapreneurship, new relationships are identified between goals and possible means of achieving them, which are then tested in practice, creating conditions for the profitable implementation of new products, services and organizational methods (Shane, Venkataraman, 2000).

New combinations of resources can arise through the coordinated actions of participants in a joint venture, alliance (Sun et al., 2021) or an international platform (Nambisan et al., 2019). Combining assets, whether in the areas of new markets, products, processes, ways of organizing and sources of supply, can represent either

a radical new balance of means and ends, or a slight modification of the existing alignment (Shane, 2012; O'Brien et al., 2019).

Among the internal corporate sources of emergence are the ability to establish partner networks inside and outside the company, an open and creative type of thinking, skillful interaction with complexity and risks, ingenuity, commitment to high standards, empathy, etc. However, the ability to search for opportunities outside the organization is equally important (Pett, Wolff, 2016).

Impact of work climate on opportunity seeking and intrapreneurship in general

Intraorganizational interaction is largely determined by the company's identity and values. As successful practices of intrapreneurship show, companies actively practicing this type of entrepreneurship skillfully create an atmosphere of prosperity (Hornsby et al., 2017). This will be facilitated the concept of design innovation, combining design thinking, user-centricity, and innovation strategies. Combining a creative corporate climate with intrapreneurship is fundamental to the success of such projects, where innovation, proactivity and self-renewal play a big role.

The influence of age on the choice between classical entrepreneurship and intrapreneurship has also been studied (Parker, 2009). It has been established that employees aged 24 to 44 years, if they have appropriate internal potential, are highly likely to decide to leave their current job and implement their ideas in an independent startup, that is, they will choose classic entrepreneurship. In turn, able-bodied individuals whose age is below or above the specified age range are significantly more likely to participate in intrapreneurship than in classical entrepreneurship

Return from intrapreneurship to classical entrepreneurship

Such precedents are also being explored. For example, Verma (2016) examines the factors that led employees not to become intrapreneurs but to become successful external, "classic" entrepreneurs. Their innovations were rejected by their parent companies or were not suitable for these companies due to lack of support, so they decided to start their own business in a high-risk environment. If employees with entrepreneurial skills are not fully supported by management to position themselves as intrapreneurs, they are forced to leave the parent company and start their own venture. More specific factors that can hinder intrapreneurship and at the same time stimulate classic entrepreneurship include:

- Employees' desire for individual achievement and recognition
- The foreignness of their innovative and creative qualities for the corporate environment

- Management's unresponsiveness to the company's renewal and the proactive employee's disappointment with this attitude
- Unwillingness of colleagues to get involved in intrapreneurial initiatives
- Reduction of internal corporate financial support due to previous failures and direct fines
- Lack of remuneration and profit distribution policy in the organization
- Excessive unconventionality and radicalism of the proposed ideas in the eyes of the company management
- Long wait for project approval from management.

Global practices for successful intrapreneurship

There are several real-world examples that illustrate the connection between entrepreneurial competencies and intrapreneurship:

Google's «20% Time» Policy: Google encourages its employees to dedicate 20% of their work hours to pursue personal projects. This policy has led to the development of innovative products like Gmail and Google Maps, showcasing how intrapreneurial behavior, fueled by employees' entrepreneurial competencies, can drive significant innovations within a corporate setting.

3M's Innovation Time Off (ITO) Program: 3M allows its employees to spend up to 15% of their working time on projects of their choice. This initiative has resulted in numerous successful products, including Post-it Notes. By empowering employees to apply their entrepreneurial skills, 3M fosters a culture of intrapreneurship, leading to continuous innovation.

Apple's Internal Incubator: Apple has a history of encouraging intrapreneurship through projects like the App Store. Employees are given the autonomy to develop and launch their apps, leveraging their entrepreneurial competencies to create successful applications that contribute to Apple's ecosystem and revenue.

Amazon's Customer Obsession: Amazon's focus on customer needs and its drive for innovation are deeply rooted in entrepreneurial competencies. The company's intrapreneurial initiatives, such as the development of Amazon Echo and Alexa, exemplify how understanding customer demands and innovative thinking can lead to disruptive products and services within a corporate environment.

Adobe Kickbox: Adobe provides its employees with a physical «Kickbox» that contains resources and instructions for developing new ideas. This intrapreneurial toolkit empowers employees to explore their entrepreneurial competencies, fostering a culture of innovation and experimentation within the organization.

These examples highlight how entrepreneurial competencies, such as creativity, opportunity recognition, risk-taking, and customer focus, drive intrapreneurial initiatives within well-established companies, leading to groundbreaking products and services.

Indian context

Many Indian entrepreneurs, who started as intrapreneurs, have already contributed greatly to the industrial development of the country. In general, India has developed a culture of support for intrapreneurship, and certain success stories have emerged. So the ITC company, within the framework of the concept interpreneurship, provides wide autonomy to staff for creative initiatives. The company purchases agricultural products directly from farmers, while providing them with online access to foreign markets, increasing their productivity and strengthening the competitiveness of the national market. Another player SAP Labs, operating in the Indian market, a subsidiary of SAP runs a program called InnVent, short for innovation and venture challenges, that encourages out-of-the-box thinking. At Hindustan Unilever the result of intrapreneurship initiatives was the formation of new routes for the distribution of products to remote areas. The success of intrapreneurial cases is based on a cause-and-effect chain: legitimized freedom of action, guarantees of remuneration, tolerance for mistakes, and comprehensive resource support develop a sense of ownership and enthusiasm among employees, which enhances a favorable, unique creative climate. In turn, incentives for cooperation expand, innovative activity intensifies, and the level of emotional and psychological attachment to the organization increases (Stander, Rothmann, 2010). Many of these companies practice action learning using the latest audiovisual aids and other educational technologies. They are exponentially increasing investment in infrastructure to create innovation. Employees are provided with mentoring, financial and infrastructural support, upward communication is encouraged and workers go beyond their specific responsibilities, which increases their motivation, engagement and sharing of unique corporate values (Srivastava, Bhatnagar, 2008). Horizontal communication, coordination of interactions and cross-support between departments are also practiced.

Setting up hypotheses

Based on the literature review, the following hypothesis has been framed

H1: *There is a relationship between entrepreneurial competency and intrapreneurship development.*

This hypothesis posits an overlap in the skill set and mindset required for entrepreneurial competency and intrapreneurship. Both roles demand the ability to recognize opportunities, manage risks associated with new ventures, and foster innovation and creativity. Entrepreneurs and intrapreneurs alike need to identify market gaps and innovative prospects, navigate risks effectively, and employ creative problem-solving

within their organizational contexts, highlighting the shared competencies between the two roles.

H2: *Working climate mediates the relationship between entrepreneurial competency and intrapreneurship development.*

The working climate, encapsulating the psychological environment within an organization, acts as a pivotal mediator between entrepreneurial competency and intrapreneurship development. Within this climate, psychological safety cultivates trust, empowering employees to utilize their entrepreneurial skills freely, fostering a culture of intrapreneurial behavior. Autonomy further drives innovation, enabling employees to initiate and innovate, while the climate's stance on risk-taking influences intrapreneurial endeavors, encouraging calculated risks. Collaboration nurtures teamwork and idea exchange, translating entrepreneurial skills into actionable intrapreneurial projects. Recognition and rewards reinforce the link between competency and intrapreneurship, emphasizing the importance of acknowledgment in promoting a culture of innovation and initiative.

Methodology

An empirical research study was carried out using a survey technique with a standardized questionnaire as research tool. It contained questions about intrapreneurial development, working climate and entrepreneurial competency. Entrepreneurial competency included opportunity competency, relationship competency, conceptual competency, organizing competency, strategic competency and commitment competency. Intrapreneurial development included new business venturing, innovativeness, self-renewal and proactiveness. The measures were studied using a five-point Likert scale (Joshi et al., 2015).

Manufacturing firms in the top five most industrialised states in India (Tamil Nadu, Maharastra, Gujarat, Uttar Pradesh and Andra Pradesh) were considered for the study. Employees in the research and development team of the manufacturing firms are the target population. A questionnaire was emailed to the Human resource departments of the manufacturing industries and asked to circulate among the workers. Total 426 responses were received. Out of which 418 responses were found fit for the study. Reliability and validity of the constructs were measured and mediation analysis is done using SPSS Macros.

A detailed description of the components studied is shown in Table 1.

Results

Measurement model Evaluation

The validity of the measurement model is examined using confirmatory factor analysis (CFA). The average variance extracted, Composite reliability and Cronbach's alpha were derived as defined in a similar study

Table 1. Questionnaire statements proposed to the respondents to estimate the considered components of the research model

Entrepreneurial Competency
I possess creative thinking skills that help in problem-solving and innovation
I am comfortable with taking calculated risks to explore new opportunities
I excel in generating innovative ideas that contribute to business growth.
I am skilled in optimizing supply chains and managing resources efficiently.
I demonstrate financial acumen in decision-making and resource allocation.
I effectively network and build relationships to facilitate business opportunities.
Intrapreneurship Development
I actively engage in new business venturing within my organization.
I contribute to innovativeness by proposing and implementing new ideas.
I am proactive in seeking opportunities for self-renewal and personal growth.
I demonstrate a proactive approach to problem-solving and decision-making.
Working Climate
My organization encourages a culture of creativity and innovation.
Employees are empowered to take initiative and make decisions independently.
There is a supportive environment that values and rewards risk-taking and experimentation.
Collaboration and teamwork are encouraged to foster idea exchange and innovation.
Note: based on the respondents' assessment using a 5-point Likert scale: (1) Strongly Disagree; (2) Disagree; (3) Neither Agree nor Disagree; (4) Agree; (5) Strongly Agree). Additional question relates to the Overall Evaluation: "How would you rate the overall entrepreneurial culture within your organization?" (answer options: Poor; Fair; Good; Very Good; Excellent).
Source hereinafter: authors, based on survey results.

(Bjornali, Støren, 2012) and the constructs are validated. Table 2 provides Cronbach's alpha which according to (Singh, Smith, 2006) is good as the value exceeds 0.80 and is found to be reliable. Discriminant validity and congruent validity were assessed using Average variance extracted, from Table 3 we see that the AVE values are above 0.5 and the correlated factors are above 0.5 which is said to be satisfactory according to (Singh, Smith, 2006).

Evaluation of the structural model

The relationship between the investigated constructs is assessed using regression values derived from AMOS path analysis.

H1: *There is a relationship between entrepreneurial competency and intrapreneurship development.*

The fit indices of the CFA and SEM conducted in AMOS 23 are shown in Table 4. According to (Byrne, 2004), the values of CFA and SEM were determined to fit.

According to the study's findings in Table 5, there is a significant association between Entrepreneurial competency and intrapreneurship development (p<0.05). Entrepreneurship competency can explain 86% of the difference in intrapreneurship development. The results were similar to those (Boon et al., 2013a)

Entrepreneurial competency plays an important role in aiding intrapreneurship development. Strategic and organizing factors are strongly related to intrapreneurship development.

Evaluation of Mediation

H2: *Working climate mediates the relationship between entrepreneurial competency and intrapreneurship development.*

The mediating role of the working climate towards the relationship between entrepreneurial competency and intrapreneurship development is analysed using Hayes process Macros (Hayes, 2012).

This study investigated the function of working climate as a moderator in the link between Entrepreneurial competency and Intrapreneurship development. The findings supported H2 by revealing a substantial indirect influence of Entrepreneurial competency on intrapreneurship development (b= 0.268, t = 5.496). Furthermore, in the presence of the mediator, the direct effect of Entrepreneurial competency on intrapreneurship development was shown to be significant (b = 0.289, p < 0.001). As a result, the working climate moderated the association between Entrepreneurial competency and intrapreneurship development to some extent. Table 5 summarises the mediation analysis.

Discussion

Firstly, the study results showed that there is a relationship between Entrepreneurial competency and intrapreneurship development in Indian manufacturing firms. These results are similar to the results of (Bjornali, Støren, 2012; Boon et al., 2013b) however, in the manufacturing setup, the conceptual and strategic factors of the entrepreneurial commitment were found to be strongly related to entrepreneurship development. Few studies have emphasised training, corporate culture and organizational work models (González-Tejero, Molina, 2022; Rasca et al., 2018) which were also considered in his study and the relationships were highlighted.

Secondly, the results from the mediation analysis showed that the working climate partially moderates the relationship between entrepreneurial competency and intrapreneurship. Several studies were done in similar areas (Gelade, Ivery, 2003; Salanova et al., 2005; Zarefard, Jeong, 2019) however a mediating effect of working climate in comparison to entrepreneurial competency and intrapreneurship development is

Table 2. **Measurement model Evaluation (CFA)**

Latent construct	CA	AVE	CR	Corr
Entrepreneurial competency				
Opportunity	0.812	0.723	0.821	0.723
Relationship	0.836	0.711	0.878	0.705
Conceptual	0.924	0.703	0.816	0.748
Organizing	0.817	0.719	0.806	0.789
Strategic	0.856	0.752	0.863	0.764
Commitment	0.803	0.741	0.841	0.748
Intrapreneurial development				
Business Venturing	0.834	0.729	0.874	0.814
Innovativeness	0.867	0.815	0.816	0.748
Self-renewal	0.851	0.836	0.857	0.761
Proactiveness	0.829	0.841	0.803	0.709
Working climate	0.816	0.869	0.856	0.736

Note: CA – Cronbach's Alpha; AVE – Average Variance Extracted; CR – Composite Reliability; Corr – Correlation..

Table 3. **The goodness of fit measures**

The goodness of fit measures	CFA Model	SEM Model
The basic goodness of fit		
Chi-square	232.789	245.268
Degrees of freedom	145	145
Absolute fit index		
Chi-square/degrees of freedom	1.426	1.502
RMSEA	0.043	0.044
GFI	0.861	0.856
AGFI	0.906	0.917
CFI	0.962	0.978
RMR	0.046	0.038
SRMR	0.024	0.003

Note: RMR < 0.08. RMSEA < 0.08. CFI > 0.95. GFI > 0.90. AGFI > 0.90. SRMR < 0.05.

Table 4. **Evaluation of the Structural model (SEM)**

Relationship	EC→ID
Standardized regression weight	0.796
Standardized estimates	0.189
p-value	0.00*
Squared multiple correlation coefficient	0.864
Hypothesis test result	Accept hypothesis

* Significance at p<0.05.

Table 5. **Mediation analysis summary**

Relationship	EC→WC→ID
Total Effect	0.542 (0.000)
Direct Effect	0.289 (0.000)
Indirect Effect	0.268
Confidence Interval (lower to upper band)	0.186 to 0.367
t-statistics	5.496
Conclusion	Partial Mediation

not been analysed. Manufacturing industries have a stronger relationship in developing intrapreneurship through entrepreneurship development factors.

The relationship between entrepreneurial competency and intrapreneurship development within Indian manufacturing firms, specific findings from the survey data provide valuable insights. Confirmatory factor analysis (CFA) confirmed the validity of the measurement model, with Cronbach's alpha values exceeding 0.80, indicating reliability. The structural equation model (SEM) further supported the relationship, revealing a significant association between entrepreneurial competency and intrapreneurship development ($p < 0.05$). Notably, strategic and organizing factors within entrepreneurial competency exhibited strong correlations with intrapreneurship development. Mediation analysis, employing the Hayes process Macros, demonstrated the moderating role of the working climate. The findings revealed a substantial indirect influence of entrepreneurial competency on intrapreneurship development ($b = 0.268$, $t = 5.496$). Additionally, the direct effect of entrepreneurial competency on intrapreneurship development remained significant ($b = 0.289$, $p < 0.001$) in the presence of the mediator, indicating partial mediation.

Furthermore, the study illuminated the underexplored area of working climate's mediating effect, showcasing its pivotal role in fostering intrapreneurship development alongside entrepreneurial competencies in manufacturing industries. This research underscores the crucial interplay between entrepreneurial competency, intrapreneurship, and the working climate, emphasizing their collective importance in enhancing innovation and competitiveness within manufacturing businesses.

Conclusion

This research explored how entrepreneurial competencies, including strategic and organizing factors, influence intrapreneurship development. The study involved 418 respondents from manufacturing firms in five industrialized states in India. Confirmatory factor analysis (CFA) validated the measurement model, demonstrating the reliability of the constructs. Structural equation modeling (SEM) revealed a significant association between entrepreneurial competency and intrapreneurship development. Notably, the study found that the working climate partially mediates the relationship between entrepreneurial competency and intrapreneurship development, emphasizing the importance of a supportive workplace environment in fostering intrapreneurial behavior.

Firstly, the research underscored the pivotal role of entrepreneurial competency in driving intrapreneurship within manufacturing firms, emphasizing the significance of strategic thinking and organizational skills in fostering innovative initiatives within corporate boundaries. Secondly, the study highlighted the nuanced influence of the working climate as a mediating factor, indicating that a positive and supportive workplace environment significantly amplifies the impact of entrepreneurial competency on intrapreneurship development. Organizations with conducive working climates are more likely to witness the effective utilization of entrepreneurial skills among their employees, leading to enhanced intrapreneurial activities. This insight is particularly vital for business leaders and policymakers, emphasizing the need to invest in creating supportive work environments that nurture creativity, risk-taking, and entrepreneurial spirit. Furthermore, the findings also imply that training programs and interventions focusing on enhancing entrepreneurial competencies, when coupled with a favorable working climate, can substantially contribute to a culture of innovation and intrapreneurship within manufacturing firms. Overall, the research provides actionable insights for businesses aiming to foster intrapreneurship, improve organizational performance, and maintain a competitive edge in the dynamic business landscape.
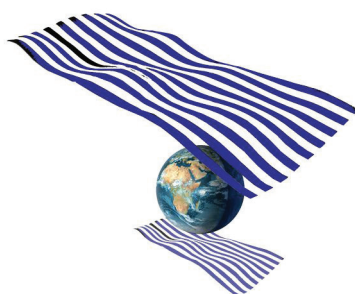
References

Ajzen I. (1991) The theory of planned behavior. *Organizational Behavior and Human Decision Processes*, 50(2), 179–211. https://doi.org/10.1016/0749-5978(91)90020-T

Alpkan L., Bulut C., Gunday G., Ulusoy G., Kilic K. (2010) Organizational support for intrapreneurship and its interaction with human capital to enhance innovative performance. *Management Decision*, 48(5), 732–755. https://doi.org/10.1108/00251741011043902/FULL/XML

Amo B.W. (2010) Corporate entrepreneurship and intrapreneurship related to innovation behaviour among employees. *International Journal of Entrepreneurial Venturing*, 2(2), 144–158. http://dx.doi.org/10.1504/IJEV.2010.034819

Antoncic B., Hisrich R.D. (2000) Intrapreneurship modeling in transition economies: A comparison of Slovenia and the United States. *Journal of Developmental Entrepreneurship*, 5(1), 21–40.

Antoncic B., Hisrich R.D. (2003) Clarifying the intrapreneurship concept. *Journal of Small Business and Enterprise Development*, 10(1), 7–24. https://doi.org/10.1108/14626000310461187

Bager T., Ottosson H., Schott T. (2010) Intrapreneurs, entrepreneurs and spin-off entrepreneurs: Similarities and differences. *International Journal of Entrepreneurship and Small Business*, 10(3), 339–358. http://dx.doi.org/10.1504/IJESB.2010.033572

Bakker A.B., Demerouti E. (2014) Job demands-resources theory. In: *Work and well-being: A complete reference guide* (eds. P.Y. Chen, C.L. Cooper), New York, NY: John Wiley & Sons, pp. 1–28.

Begeç S., Arun K. (2021) The bottleneck of intrapreneurship: Are social positions and held expectations constraints in organizations' entrepreneur process? A conceptual view. *Journal of Entrepreneurship in Emerging Economies*, 13(1), 131–151. https://doi.org/10.1108/JEEE-08-2019-0120/FULL/XML

Belousova O., Gailly B. (2013) Corporate entrepreneurship in a dispersed setting: Actors, behaviors, and process. *International Entrepreneurship and Management Journal*, 9(3), 361–377. https://doi.org/10.1007/s11365-013-0259-2

Bjornali E.S., Støren L.A. (2012) Examining competence factors that encourage innovative behaviour by European higher education graduate professionals. *Journal of Small Business and Enterprise Development*, 19(3), 402–423. https://doi.org/10.1108/14626001211250135/FULL/XML

Blanka C. (2018) An individual-level perspective on intrapreneurship: A review and ways forward. *Review of Managerial Science*, 12(1), 1–43. https://doi.org/10.1007/s11846-018-0277-0

Bolino M.C., Turnley W.H., Averett T. (2003) Going the extra mile: Cultivating and managing employee citizenship behavior. *Academy of Management Perspectives*, 17(3), 60–73. https://doi.org/10.5465/AME.2003.10954754

Boon J., Van der Klink M., Janssen J. (2013a) Fostering intrapreneurial competencies of employees in the education sector. *International Journal of Training and Development*, 17(3), 210–220. https://doi.org/10.1111/IJTD.12010

Bosma N., Wennekers S., Guerrero M., Amoros J.E., Martiarena A., Singer S. (2013) *Global Entrepreneurship Monitor. Special Report on Entrepreneurship Employee Activity,* Wellsley, LA: Babson College; Santiago de Chile: Universidad Dessarollo; Kuala Lumpur; Tun Abdul Razak Universiti.

Buekens W. (2014) Fostering Intrapreneurship: The Challenge for a New Game Leadership. *Procedia Economics and Finance*, 16, 580–586. https://doi.org/10.1016/S2212-5671(14)00843-0

Byrne B.M. (2004) Testing for multigroup invariance using AMOS graphics: A road less traveled. *Structural Equation Modeling*, 11(2), 272–300. https://doi.org/10.1207/S15328007SEM1102_8

Camelo-Ordaz C., Fernandez-Alles M., Ruiz-Navarro J., Sousa-Ginel E. (2012) The intrapreneur and innovation in creative firms. *International Small Business Journal,* 30 (5), 513–535. https://doi.org/10.1177/0266242610385396

Chakrabarti A., Vidal E., Mitchell W. (2011) Business transformation in heterogeneous environments: The impact of market development and firm strength on retrenchment and growth reconfiguration. *Global Strategy Journal*, 1, 6–26. https://doi.org/10.1002/gsj.3

De Keyser B., Vandenbempt K. (2023) Processes of practice in the realm of theory: Unveiling the dynamics of academic intrapreneurship. *Technovation,* 126(C), 102811. https://doi.org/10.1016/j.technovation.2023.102811

de Villiers-Scheepers M.J. (2012) Antecedents of strategic corporate entrepreneurship. *European Business Review*, 24(5), 400–424. https://doi.org/10.1108/09555341211254508

Dörnyei Z., Al-Hoorie A.H. (2017) The Motivational Foundation of Learning Languages Other than Global English: Theoretical Issues and Research Directions. *The Modern Language Journal*, 101(3), 455–468. https://doi.org/10.1111/MODL.12408

Edquist C., Hommen L., McKelvey M.D. (2001) *Innovation and employment: Process versus product innovation*, Cheltenham: Edward Elgar Publishing.

Felício J.A., Rodrigues R., Caldeirinha V.R. (2012) The effect of intrapreneurship on corporate performance. *Management Decision*, 50(10), 1717–1738. https://doi.org/10.1108/00251741211279567

Galvan-Vela E., Sanchez-Limon M. (2017) Autonomy and rewards as organizational factors triggering intrapreneurship. *Ciencias Administrativas. Teoría y Praxis*, 2(13), 237–249 (in Spanish).

Gawke J.C., Gorgievski M.J., Bakker A.B. (2017) Employee intrapreneurship and work engagement: A latent change score approach. *Journal of Vocational Behavior,* 100, 88–100. https://doi.org/10.1016/j.jvb.2017.03.002

Gelade G.A., Ivery M. (2003) The Impact of Human Resource Management and Work Climate on Organizational Performance. *Personnel Psychology*, 56(2), 383–404. https://doi.org/10.1111/J.1744-6570.2003.TB00155.X

González-Tejero C.B., Molina C.M. (2022) Training, corporate culture and organizational work models for the development of corporate entrepreneurship in SMEs. *Journal of Enterprising Communities*, 16(1), 168–188. https://doi.org/10.1108/JEC-12-2021-0178/FULL/XML

Hayes A. (2012) *PROCESS: A versatile computational tool for observed variable mediation, moderation, and conditional process modeling* (White Paper). https://is.muni.cz/el/1423/podzim2014/PSY704/50497615/hayes_2012_navod_process.pdf

Hernández-Perlines F., Ariza-Montes A., Blanco-González-Tejero C. (2022) Intrapreneurship research: A comprehensive literature review. *Journal of Business Research,* 153, 428–444. https://doi.org/10.1016/j.jbusres.2022.08.015

Hornsby J.S., Kuratko D.F., Shepherd D.A., Bott J.P. (2009) Managers' corporate entrepreneurial actions: Examining perception and position. *Journal of Business Venturing*, 24(3), 236–247. https://doi.org/10.1016/j.jbusvent.2008.03.002

Joshi A., Kale S., Chandel S., Pal D.K. (2015) Likert Scale: Explored and Explained. *Current Journal of Applied Science and Technology,* 7(4), 396–403. https://doi.org/10.9734/BJAST/2015/14975

Kanungo R.N., Misra S. (2016) Managerial Resourcefulness: A Reconceptualization of Management Skills. *Human Relations*, 45(12), 1311–1332. https://doi.org/10.1177/001872679204501204

Kassa A.G., Raju R.S. (2015) Investigating the relationship between corporate entrepreneurship and employee engagement. *Journal of Entrepreneurship in Emerging Economies*, 7(2), 148–167. https://doi.org/10.1108/JEEE-12-2014-0046/FULL/XML

Klofsten M., Urbano D., Heaton S. (2021) Managing intrapreneurial capabilities: An overview. *Technovation*, 99,102177. https://doi.org/10.1016/j.technovation.2020.102177

Kovid R.K., Bhati B., Sharma G.M. (2021) Entrepreneurial Competencies, Institutional Voids and Performance of Small and Medium Enterprises: Evidence from an Emerging Economy. *Vision* (forthcoming). https://doi.org/10.1177/09722629211058809

Kuratko D.F., Audretsch D.B. (2013) Clarifying the domains of corporate entrepreneurship. *International Entrepreneurship and Management Journal*, 9, 323–335. https://doi.org/10.1007/s11365-013-0257-4

Matthews C.H., Schenkel M.T., Ford M.W., Human S.E. (2009) Comparing nascent entrepreneurs and intrapreneurs and expectations of firm growth. *Journal of Small Business Strategy,* 20(1), 53–80.

Menzel H.C., Aaltio I., Ulijn J.M. (2007) On the way to creativity: Engineers as intrapreneurs in organizations. *Technovation*, 27(12), 732–743. https://doi.org/10.1016/J.TECHNOVATION.2007.05.004

Mom T.J.M., Fourné S.P.L., Jansen J.J.P. (2015) Managers' work experience, ambidexterity, and performance: The contingency role of the work context. *Human Resource Management,* 54(S1), 133–153. http://dx.doi.org/10.1002/hrm.21663

Mom T.J.M., Oshri I., Volberda H.W. (2012) The skills base of technology transfer professionals. *Technology Analysis & Strategic Management*, 24(9), 871–891. https://doi.org/10.1080/09537325.2012.718663

Mudambi R., Mudambi S.M., Navarra P. (2007) Global innovation in MNCs: The effects of subsidiary selfdetermination and teamwork. *Journal of Product Innovation Management*, 24, 442–455. https://doi.org/10.1111/j.1540-5885.2007.00262.x

Mustafa M., Martin L., Hughes M. (2016) Psychological ownership, job satisfaction, and middle manager entrepreneurial behavior. *Journal of Leadership & Organizational Studies*, 23(3), 272–287. https://doi.org/10.1177/1548051815627360

Nambisan S., Zahra S.A., Luo Y. (2019) Global platforms and ecosystems: Implications for international business theories. *Journal of International Business Studies*, 50, 1464–1486. https://doi.org/10.1057/s41267-019-00262-4

Neessen P., Caniels M.C., Vos B., De Jong J.P. (2019) The intrapreneurial employee: Toward an integrated model of intrapreneurship and research agenda. *International Entrepreneurship and Management Journal*, 15(2), 545–571. https://doi.org/10.1007/s11365-018-0552-1

O'Brien D., Scott P.S., Andersson U., Ambos T., Fu N. (2019) The microfoundations of subsidiary initiatives: How subsidiary manager activities unlock entrepreneurship. *Global Strategy Journal*, 9, 66–91. https://doi.org/10.1002/gsj.1200

Park S.H., Kim J.N., Krishna A. (2014) Bottom-up building of an innovative organization: Motivating employee intrapreneurship and scouting and their strategic value. *Management Communication Quarterly*, 28(4), 531–560. https://doi.org/10.1177/0893318914541667

Parker S.C. (2011) Intrapreneurship or entrepreneurship? *Journal of Business Venturing*, 26(1), 19–34. https://doi.org/10.1016/j.jbusvent.2009.07.003

Parker S.K., Bindl U.K., Strauss K. (2010) Making things happen: A model of proactive motivation. *Journal of Management*, 36(4), 827–856. https://doi.org/10.1177/0149206310363732

Peña I. (2004) Business Incubation Centers and New Firm Growth in the Basque Country. *Small Business Economics*, 22(3), 223–236. https://doi.org/10.1023/B:SBEJ.0000022221.03667.82

Pett T., Wolff J.A. (2016) Entrepreneurial orientation and learning in high and low-performing SMES. *Journal of Small Business Strategy*, 26(2), 71–86.

Pinchot G. (1985) *Intrapreneuring*, New York: Harper & Row.

Pinchot G., Pellman R. (1999) *Intrapreneuring in action: A handbook for business innovation*, Berrett-Koehler Publishers.

Poduška Z., Nedeljković J., Nonić D., Ratknić T., Ratknić M., Živojinović I. (2020) Intrapreneurial climate as momentum for fostering employee innovativeness in public forest enterprises. *Forest Policy and Economics*, 119, 102281. https://doi.org/10.1016/J.FORPOL.2020.102281

Rasca L., Deaconu A., True S. (2018) From successful SMEs to entrepreneurial society and the importance of the entrepreneurial mindset. In: *Doing Business in Europe. Contributions to Management Science* (ed. A. Dima), Cham: Springer, pp. 315–328. https://doi.org/10.1007/978-3-319-72239-9_15/COVER

Reuber A.R., Knight G.A., Liesch P.W., Zhou L. (2018) International entrepreneurship: The pursuit of entrepreneurial opportunities across national borders. *Journal of International Business Studies*, 49, 395–406. https://doi.org/10.1057/s41267-018-0149-5

Rigtering J.C., Weitzel U. (2013) Work context and employee behaviour as antecedents for intrapreneurship. *International Entrepreneurship and Management Journal*, 9(3), 337–360. https://doi.org/10.1007/s11365-013-0258-3

Salanova M., Agut S., Peiró J.M. (2005) Linking organizational resources and work engagement to employee performance and customer loyalty: The mediation of service climate. *Journal of Applied Psychology*, 90(6), 1217–1227. https://doi.org/10.1037/0021-9010.90.6.1217

Santos-Vijande M.L., Lopez-Sanchez, J.A., Loredo E., Rudd J., Lopez-Mielgo N. (2022) Role of innovation and architectural marketing capabilities in channelling entrepreneurship into performance. *Journal of Innovation & Knowledge*, 7(2), 100174. https://doi.org/10.1016/j.jik.2022.100174

Schneider B., Bowen D.E. (1993) The service organization: Human resources management is crucial. *Organizational Dynamics*, 21(4), 39–52. https://doi.org/10.1016/0090-2616(93)90032-V

Shane S. (2012) Reflections on the 2010 "AMR" decade award: Delivering on the promise of entrepreneurship as a field of research. *Academy of Management Review*, 37, 10–20. https://doi.org/10.5465/amr.2011.0078

Singh P.J., Smith A. (2006) An empirically validated quality management measurement instrument. *Benchmarking: An International Journal*, 13(4), 493–522. https://doi.org/10.1108/14635770610676317

Sinha N., Srivastava K.B.L. (2013) Association of Personality, Work Values and Socio-cultural Factors with Intrapreneurial Orientation. *The Journal of Entrepreneurship*, 22(1), 97–113. https://doi.org/10.1177/0971355712469186

Srivastava P., Bhatnagar J. (2008) Talent acquisition due diligence leading to high employee engagement: Case of Motorola India MDB. *Industrial and Commercial Training*, 40(5), 253–260. https://doi.org/10.1108/00197850810886496

Sun P., Deng Z., Wright M. (2021) Partnering with Leviathan: The politics of innovation in foreign-hoststate joint ventures. *Journal of International Business Studies*, 52, 595–620. https://doi.org/10.1057/s41267-020-00340-y

Tehseen S., Ramayah T. (2015) Entrepreneurial competencies and smes business success: The contingent role of external integration. *Mediterranean Journal of Social Sciences*, 6(1), 50–61. https://doi.org/10.5901/MJSS.2015.V6N1P50

Urbano D., Turro A. (2013) Conditioning factors for corporate entrepreneurship: An in (ex) ternal approach. *International Entrepreneurship and Management Journal*, 9(3), 379–396. https://doi.org/10.1007/s11365-013-0261-8

Verbeke A., Yuan W. (2022) Rethinking intrapreneurship in the established MNE. *Global Strategy Journal*, 12(4), 738–758. https://doi.org/10.1002/gsj.1461

Verma N. (2016) *Role of Intrapreneurs in the Industrial Development of India (An Empirical Study)* (SSRN Paper 2988224). http://dx.doi.org/10.2139/ssrn.2988224

Wahyudi I., Suroso A.I., Arifin B., Syarief R., Rusli M.S. (2021a) Multidimensional aspect of corporate entrepreneurship in family business and SMEs: A systematic literature review. *Economies*, 9(4), 156. https://doi.org/10.3390/economies9040156

Wickramaratne A., Kiminami A., Yagi H. (2014) Entrepreneurial Competencies and Entrepreneurial Orientation of Tea Manufacturing Firms in Sri Lanka. *Asian Social Science*, 10(18), 50. https://doi.org/10.5539/ASS.V10N18P50

Woo H.R. (2018) Personality traits and intrapreneurship: The mediating effect of career adaptability. *Career Development International*, 23(1). https://doi.org/10.1108/CDI-02-2017-0046

Yang Y., Narayanan V.K., Zahra S. (2009) Developing the selection and valuation capabilities through learning: The case of corporate venture capital. *Journal of Business Venturing*, 24(3), 261–273. https://doi.org/10.1016/j.jbusvent.2008.05.001

Zampetakis L.A., Beldekos P., Moustakis V.S. (2009) "Day-to-day" entrepreneurship within organisations: The role of trait Emotional Intelligence and Perceived Organisational Support. *European Management Journal*, 27(3), 165–175. https://doi.org/10.1016/j.emj.2008.08.003

Zarefard M., Jeong D.Y. (2019) The influence of entrepreneurial competencies of project leader on innovative idea generation in the ICT firms. *Journal of Theoretical and Applied Information Technology*, 97(17), 4612–4622.