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THE RISK AWARENESS OF SOVEREIGN WEALTH FUNDS IN RELATION TO ESG ASSETS: DO BIGGEST WORLD INSTITUTIONAL INVESTORS ACT SUSTAINABLY?

Marty-Jörn Klein[1]✉, Gabriela Chmelíková[1], Jozef Palkovič[2]

[1] *Mendel University in Brno, Czech Republic*
[2] *Slovak University of Agriculture in Nitra, Slovakia*

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ABSTRACT

This paper investigates the dependence of the investment behavior of Sovereign Wealth Funds (SWFs) on the Environmental, Social, and Governance (ESG) performance of their underlying investments in public equity holdings during the period of 2007 to 2022 collectively overseeing a substantial 71% of total public equity holding investments by SWFs globally. The unique data set with ESG control variables consist of mainly self-reported Corporate Social Responsibility (CSR) ESG information (ESG rating from Refinitiv/LSEG) and dynamic risk assessed ESG information purely based on external evaluation of the firms (Reputational Risk Indicator from RepRisk). The control variable which monitors the Corporate Social Irresponsibility (CSI) of target companies is novel to previous studies. Our findings suggest that SWFs still consider self-reported CSR information more than public CSI data in their investment decisions. Furthermore, a change in past ESG data of underlying public equity holdings – both CSR and CSI – does not seem to have a significant effect on the investment into underlying public equity holdings. Our conclusions could help to encourage greater ESG integration into SWF investment strategies and promote sustainable investing practices more broadly not limited to liquid assets.

KEY WORDS

Sovereign Wealth Funds, ESG, reputation risk, Corporate Social Responsibility, Corporate Social Irresponsibility

JEL CODES

D81, F64, G11, G32, M14, Q01

1 INTRODUCTION

Sovereign Wealth Funds (SWFs), alongside pension funds and insurance companies, rank as formidable global institutional investors, commanding considerable influence and sizeable financial power (Rozanov, 2005; Aggarwal and Goodell, 2018). What makes them a common

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community is the fact that they are state-owned with governance bodies influencing their aims and taking responsibility for their outcomes (Aizenman and Glick, 2009; Grasso, 2017). Many are financed by the sale of commodities, e.g., oil and gas, like those SWFs from Norway, Kuwait, and Abu Dhabi (Bassan, 2015). SWFs have immense impacts on the sustainability of economies (Sharma, 2017; Stulz, 2005). Over the last decade, there has been an increased emphasis on the three pillars of social, economic, and environmental sustainability by both theorists and practitioners alike. As highlighted in studies by Bautista-Puig et al. (2021), Chmelíková and Redlichová (2020), and Kölbel et al. (2020), social sustainability refers to the well-being and quality of life of individuals and communities. Economic sustainability refers to the creation of economic systems that promote long-term growth and stability, while environmental sustainability focuses on preserving natural resources and reducing the negative impacts of human activities on the environment.

The influence of SWFs on the resilience of the world economy is significant. As per the studies conducted by Adonu (2020) and Chmelíková and Redlichová (2013), SWFs are instrumental in promoting sustainable economic growth by investing in innovative technologies and sustainable business practices. SWFs allocate their investments across diverse sectors, encompassing renewable energy, clean technology, sustainable agriculture, and other areas, showcasing their typically broad investment portfolios. By doing so, they can contribute to the development of a sustainable economy and help to reduce carbon emissions. Even though their investment behavior has been analyzed in prior research (Liang and Renneboog, 2020; Dai et al., 2022), their focused investment decision-making regarding several asset classes remains largely opaque (Aggarwal and Goodell, 2018). Little is known about the transmission channels that allow for unsustainable development factors to impact SWFs' investment decisions (Avendano, 2010). The objectives or purposes of SWFs can play a significant role in their disclosure behavior on Environment, Social, and Governance- (ESG-) and Sustainable Development Goals- (SDG-) related topics. It is important that SWFs are transparent in their disclosure behavior, regardless of their objectives, to ensure that their investments are aligned with broader sustainable development objectives (Chmelíková and Somerlíková, 2018; Klein, 2021).

With global assets under management of USD 10.2 trillion (SWF Institute, 2023a) it is important to understand whether there is a common denominator which drives the investment decisions of SWFs. During the global financial crisis in 2008, it was this opaqueness which got the attention of global policy makers. On the one hand, SWFs were invited to stabilize financial markets through their investments in listed equity. On the other hand, SWFs thereby gained significantly more influence in listed companies (Wagner, 2013). SWFs have answered with the establishment of the International Forum of SWFs (IFSWF), and many signed the Santiago Principles in 2009 to demonstrate their willingness to collaborate and adopt greater transparency in their operations (IWG, 2008). The desire to improve transparency is also reflected in the creation of the Linaburg-Maduell Transparency Index (LMTI) introduced in 2008 (SWF Institute, 2023a). However, do SWFs care about the sustainability of their investments, and what are the drivers of their responsible behavior?

There is growing body of literature (Liang and Renneboog, 2020; Farag et al., 2022) dealing with the ability of SWFs to incorporate ESG considerations into their investment decisions. The studies are based on the evaluation of the relationship between ownership stakes in underlying companies and their ESG scores. They reveal that SWFs consider both historical ESG performance and recent improvements in ESG scores when acquiring ownership stakes in publicly traded companies, as highlighted by Liang and Renneboog (2020). However, ESG scores suffer from several shortcomings. First, they are to a large extend based on company self-reported CSR information which makes their content opaque (Bautista-Puig et al., 2021; Jory et al., 2010). In other cases, ESG ratings calculated by different providers disagree

substantially (Berg et al., 2022). The divergence in ESG measurements occurs due to the varying scope, measurement, and weight of ESG parameters. Most have already developed special, at least yearly, reports and use their homepage for publication (Klein, 2021). This holds also true for publications regarding sustainability (Maslova, 2020), e.g., the One Planet Sovereign Wealth Funds initiative (One Planet SWFs, 2023) as well as ESG and SDG reporting (Klein, 2021). To overcome the obstacles presented by self-disclosed information gleaned from firms' annual reports, reputation measures revealed by the media can be used (Kölbel et al., 2017). The root of this idea is that many studies (Chava, 2014; Oikonomou et al., 2014) differentiate between Corporate Social Responsibility (CSR) that is self-disclosed in a firm's annual report and its negative counterpart Corporate Social Irresponsibility (CSI) which is usually revealed by media and social networks.

We follow the same logic and suggest that while traditional ESG scores informing on the CSR performance are to a large extend based on company self-reported CSR information, the ESG indicator derived from reputation risk reflects real behavior of firms related to CSI. Inspired by the preceding body of work, our study empirically delves into the research question of the extent to which SWFs respond to fluctuations in the ESG ratings of their underlying assets, seeking to elucidate the dynamics and implications of ESG considerations in the investment decision-making process of SWFs. The research question to be analyzed is:

Are SWF sensitive to ESG CSI data when considering an investment in public equity holdings?

Our research contributes to the literature on the impact of CSI factors on the investment decision-making process of SWFs, particularly in relation to their investments in publicly traded equity holdings. This analysis endeavors to bridge the existing research gap by examining the relationship between SWF ownership and the ESG reputation risk of target firms. To measure the CSI associated with individual firms, we utilized an objective indicator based on external evaluations of the target companies. Specifically, we employed the RepRisk dataset, which monitors media coverage of incidents affecting the ESG performance of firms based on a dynamic risk assessment methodology.

The remainder of our paper proceeds as follows: part two reviews previous empirical studies focusing on the relationship between the ESG performance of target firms and SWF ownership stake. Based on this overview, we develop our hypotheses. Part three describes the methods, the data used to answer our research questions, and the model limitations. The analysis presented in the fourth part applies an econometric approach to identify the extent to which changing the ESG performance of target firms influences the ownership stake held by SWFs. Results are shown and discussed. The final part five contains a conclusion and outlook discussion of our main results and conclusions, the particular limitations of our study, and including possible further research.

2 THEORETICAL BACKGROUND AND HYPOTHESES

There are several types of incentives for SWFs to care about their portfolio companies' ESG- and SDG-related practices. First, SWFs operate on behalf of whole generations and should act in their interests. Furthermore, responsible investing has emerged as an integral aspect of societal preferences, reflecting an increasing awareness and consideration of ESG factors in investment decision-making. Recent empirical research has unveiled a positive association between a firm's CSR profile and its financial performance, as evidenced by studies conducted by Malik et al. (2023) and Dyck et al. (2018). Additionally, Ding et al. (2019) observe a positive relation between a firm's CSR profile and socio-economic conditions of the geographic location of their headquarters. These facts constitute important reasons for responsible be-

havior by the governments which direct SWFs. However, the responses by SWFs to changes in the ESG activities of underlying companies differ broadly. An expanding corpus of scholarly literature has been dedicated to examining the extent and way SWFs integrate ESG considerations into their investment decision-making processes, highlighting the increasing scrutiny directed towards this topic. There are also several empirical studies focusing on the inverse relationship – meaning the influence of SWF ownership on firm ESG score. (Farag et al., 2022).

The first direction of research taken on the mutual relationship between SWFs and the ESG performance of their underlying publicly listed corporations is more comprehensive than the opposite direction taken by other researchers (Bernstein et al., 2013). Liang and Renneboog (2020) showed in a sample of 24 SWFs – representing 83.75% of total SWF public equity holding assets under management (AuM) from 2009 to 2018 – that SFWs consider both the historical and recent ESG performance of publicly listed companies when making decisions regarding ownership stakes, showcasing the significance of ESG factors in their investment strategies. They identified the major drivers of this relationship, which are the explicit or implicit ESG policy of the SWF and its level of transparency. The origin of SWFs emerged as a crucial factor influencing the investment decision-making process, with SWFs from developed countries and countries with civil law origins demonstrating higher sensitivity to ESG considerations in comparison to their counterparts from developing regions, as elucidated by Megginson and Fotak (2015). According to Liang and Renneboog (2020), firms with higher ESG ratings are more frequently targeted for ownership by SWFs, who also tend to acquire larger ownership stakes in such companies. Many SWFs with ESG policies hold the belief that proficient management of ESG risks and opportunities contributes to maximizing returns on investments, underlining the growing recognition of the link between ESG factors and financial performance. Their main control variable – the ESG score of the underlying companies – was for the purposes of their study collected from Thomson Reuters' Asset4 ESG ratings.

Use of ESG ratings from one source decreases the reliability of the results, while Berg et al. (2022) claim that ESG ratings from different providers disagree substantially. The authors detected several sources of these divergences. Measurement methodology contributes 56% of the divergence, scope of ratios 38%, and their weight 6%. To overcome this shortcoming, the authors suggested that the control variable of the firm's ESG engagement should be based on several sources. Dai et al. (2022) conducted a study investigating the significance of a firm's ESG engagement for the investment decision-making process of SWFs, shedding light on the evolving considerations and dynamics surrounding ESG factors affecting SWF investments. Their sample covered all SWF investments in publicly traded US firms over the period 2003–2018. Their findings confirmed that ESG is an important factor for SWFs when making investment decisions and showed that SWF ownership in the target firm increased the probability that higher ESG engagement would attract more SWFs to invest. The authors used a control variable of ESG engagement more comprehensive than that of Liang and Renneboog (2020). The information on ESG performance came from the Kinder Lydenburg and Domini database, which is a standard source for CSR measurement. This database deploys information from financial statements, annual reports, media, governmental reports, and employee surveys.

In contrast to previous studies on this relationship, we use the ESG indicator based on the irresponsible behavior of target firms instead of traditional ESG rating as the main control variable. The point is that ESG indicators informing about irresponsible behavior is a third-party evaluation, which according to Kölbel et al. (2017) results in fundamental contrast to CSR regarding the way the information is created and distributed. Typically, traditional ESG ratings are based on CSR information which is self-disclosed by firms and distributed in CSR reports (Amran et al., 2021; Bischoff and Wood, 2019). ESG reputation risk information,

in contrast, is created by external evaluators and typically distributed in the media and social networks. To verify this conjecture, we deploy in our model two measures on ESG performance controlling for both Corporate Social Responsibility (ESGR) and its negative counterpart Corporate Social Irresponsibility (ESGI). The latter one becomes our main control variable as this constitutes the central contribution of our article – to examine the investment decision – making process of SWFs regarding public equity holdings and their ESGI behavior. Based on this we hypothesize a negative effect of irresponsible behavior of underlying public equity holdings on the SWFs investment behavior.

This leads us to the following two hypotheses that are based on underlying rationales from existing literature which are consequently to be tested and either accepted or rejected:

Hypothesis 1: Influence of public equity holding CSI data on the investment decision of SWFs.

H_1: *Public equity holding Corporate Social Irresponsibility data has a pronounced influence on the investment decision of SWFs.*

To test and then possibly find support for the hypothesis, the following alternative null hypothesis has been formulated:

H_1 null: *There is no influence of public equity holding Corporate Social Irresponsibility data on the investment decision of SWFs regarding public equity holdings.*

Hypothesis 2: Influence of public equity holding CSI data compared to company self-reported CSR information on the investment decision of SWFs.

H_2: *The influence of public equity holding Corporate Social Irresponsibility data on the investment decision of SWFs is not higher than the influence of company self-reported CSR information.*

To test and then possibly find support for the hypothesis, the following alternative null hypothesis has been formulated:

H_2 null: *The influence of public equity holding Corporate Social Irresponsibility data on the investment decision of SWFs is higher than the influence of company self-reported CSR information.*

3 METHODS, DATA, AND MODEL

3.1 Methods

We aim to investigate to what extent the change in ESG CSI data of an underlying equity holding is linked to additional investment by SWFs in these holding.

Our empirical strategy to test our hypothesis is based on an estimation of logit regression. We take the change in investor holdings and estimate the model with a binary dependent variable (1 for investment, 0 for no further investment and disinvestment). The model assumes among other assumptions that the observations should be unrelated to each other. In words the occurrence of one observation should not have any influence on the occurrence of another. Additionally it is assumed that there is a linear relationship between the variables and the log odds of the dependent variable. We will assess this assumption by conducting exploratory data analysis and plotting the variables against the log odds of the variable. Moreover it is important to have no multicollinearity among the variables. Multicollinearity refers to a situation where two or more independent variables are highly correlated with each other which can lead to estimates. We will evaluate this assumption by examining a correlation matrix. Furthermore we have ensured a large sample size for our analysis. Having a sufficient number of number of observations to predictor variables helps ensure that our parameter estimates are stable, and our inferences are reliable.

An econometric approach is used to quantify the impact of independent variables on the investment decision of SWFs.

We utilize the software SAS Studio 3.81 which is an integrated development environment (IDE) offered by SAS Institute for managing data conducting analysis and programming.

3.2 Data

We take the biggest SWFs as investors, ranked by total assets under management (AuM) (SWF Institute, 2023b), and define a minimum level of relevance at AuM $\geq$ USD 25bn as of 31 December 2021. These criteria allow us to rank 1–32 out of 97 total SWFs. As presented in Tab. 1, the total AuM coverage of the selected SWFs is 95% of all SWF AuM and 96% of all SWF public equity holdings. Amongst those 32 SWFs, public equity holdings are officially available for 24 SWFs (Refinitiv/LSEG data). This is a total AuM coverage of 87% of all SWF AuM and 94% of all SWF public equity holdings. AuM data is derived from the Sovereign Wealth Fund Institute (SWFI).

To further focus our analysis on the most significant ESGI change cases, we consider the following: first, we analyze the involvement of the aforementioned 24 SWFs in ten public equity holding special events/scandal cases, e.g., British Petroleum (2010), Volkswagen (2015), and Boeing (2019). Involvement is defined as investment and disinvestment in at least 1 out of 10 investments during 2007–2022.

Second, we derive from the scandal case single events the following seven scandal case industries: pharmaceuticals and biotechnology, automobiles and parts, support services (industrial goods and services), oil and gas, food and beverage, chemicals, and banks.

This leads us to the final set of eleven SWFs for the analysis, as outlined in Tab. 2.

As presented in Tab. 3, the final sample of selected eleven SWFs account for 62% of total global SWF AuM and 71% of all SWF public equity holdings.

Tab. 1: Sample of SWFs by AuM

	AuM (USDT)	**% of all SFW AuM**	**Public equity holdings (USDT)**	**% of all SWF public equity holdings**
Ranked 1–32 (out of 97) with total AuM $\geq$ USD 25bn	8.42	95%	3.38	96%
24 (out of 32) with available public equity holding data	7.70	87%	3.30	94%

Sources: Refinitiv/LSEG, SWF Institute

Tab. 2: Focus SWFs for further analysis

#	**Name**	**Abbreviation**	**Country**
1	Government Pension Fund Global / Norges Bank Investment Management	GPFG	Norway
2	China Investment Corporation	CIC	China
3	Abu Dhabi Investment Authority	ADIA	United Arab Emirates
4	Kuwait Investment Authority	KIA	Kuwait
5	SAMA Foreign Holdings	SAMA	Saudi Arabia
6	GIC Private Limited (Government of Singapore Investment Corporation)	GIC	Singapore
7	Temasek Holdings	Temasek	Singapore
8	National Social Security Fund	NSSF	China
9	Korea Investment Corporation	KIC	Korea
10	Alberta Investment Management Corporation	Alberta	Canada
11	(Texas) Permanent School Fund	PSF	USA

Sources: Refinitiv/LSEG, SWF Institute

Tab. 3: Sample SWF by AuM

	AuM (USDT)	% of all SWF AuM	Public equity holdings (USDT)	% of all SWF public equity holdings
Ranked 1–32 (out of 97) with total AuM ≥ USD 25bn	8.42	95%	3.38	96%
24 (out of 32) with available public equity holding data	7.70	87%	3.30	94%
11 (out of 32) for analysis of CSI awareness regarding enlarged scandal case industry scope	5.52	62%	2.50	71%

Sources: Refinitiv/LSEG, SWF Institute

3.3 Model

3.3.1 Variables and Descriptive Statistics

The relationship between equity holding investments and our explanatory factors is investigated with the application of a logit model. Our binary dependent variable Y (1 for investment, 0 for no further investment and disinvestment) is represented by the change in the number of stocks in the underlying public equity holding. Our study uses objective indicators to measure firms' ESG data, which is based on external evaluation of the firms. We deploy the RepRisk dataset, which tracks media coverage of incidents influencing the ESG performance of firms. Our main control variable is represented by the ESG CSI by one lag (ESGI_{t-1}) factor which is an objective measure of CSR performance delivered by RepRisk and specifically the RepRisk Index (RRI). The ESGI is followed by a set of additional independent firm-specific variables describing financial performance.

ESGI serves as an indicator measuring how attention the media and stakeholders give to ESG matters. The ESGI calculation considers factors, including the reach of information sources how when ESG risk incidents occur and the nature of those incidents. These factors are analyzed to determine and quantify challenges faced by a company based on its ESG performance and impact. The severity and uniqueness of these issues are also taken into consideration. This information is then used to generate a risk score, which helps companies prioritize their efforts, in addressing ESG risks. However, unlike some tools used to assess risk, the ESGI does not consider the order in which incidents occur. This means that it does not prioritize incidents based on their sequence. In our study we utilize the ESGI that considers the significance of ESG risk incidents. It focuses on how a company or project has been exposed to a specific ESG risk. The ESGI places emphasis, on exposed companies and projects because they are more responsive to exposures compared to those, with extensive past exposure.

The approach utilized in this scenario remains consistent regardless of whether the problem falls under the categories of Environment (E), Social (S), or Governance (G). The significance assigned to ESG concerns is not influenced by factors such, as industry or country. The ESGI approach does not differentiate between E, S or G elements. Instead, it calculates based on the connections a company has with all combined E, S or G issues. This methodology enables us to gauge a company's level of involvement with ESG matters without focusing on E, S or G components. The main objective of this methodology is to assess a company's performance in terms of ESG by considering its engagement with social and governance issues without any bias, towards sectors or countries.

When assessing a company's ESG performance it is crucial to recognize that ESG breakdowns should not be utilized for comparing companies. Instead, their primary purpose is to monitor how a company's ESG exposure evolves over time. Relying solely on ESG breakdowns for comparisons can be misleading due to variations in reporting standards and ESG factors among companies. Therefore, it is advisable to utilize ESG breakdowns as a tool, for examining the progress and enhancements in a company's ESG performance than directly comparing it with entities.

The ESGI score is measured on a scale of zero, to 100 with a score indicating risk exposure, for the company. Tab. 4 shows the different ESGI ranges that categorize these scores.

Tab. 4: ESGI ranges and corresponding risk exposure

ESGI ranges	Risk exposure
0–25	low risk
26–49	medium risk
50–59	high risk
60–74	very high risk
75–100	extremely high risk

Sources: RepRisk

It is anticipated that the ESGI for most large multinational organizations will fall within the range of 26–50, given their extensive global footprint and associated exposure to various ESG risks. Tab. 5 (see page 13) presents all the variables, including definitions and summary statistics that we use in our model.

All variables are consistently lagged by one year. Focus variables for ESG CSR and CSI are additionally lagged by two years related to one year lag. This will additionally lead to better understanding, more accurate estimation, and improved forecasting of economic relationships and phenomena.

The change in ESG CSI represented by the *Difference in ESG CSI*, $\text{DESGI}_{(t-2,t-1)}$, tells us about the annual change in the company's ESGI, calculated as the difference between the lagged values $t-1$ and $t-2$. The $\text{DESGI}_{(t-2,t-1)}$ can be positive or negative. A positive $\text{DESGI}_{(t-2,t-1)}$ means that the ESGI has grown from $t-2$ to $t-1$, and a higher ESGI means increased risk. A negative $\text{DESGI}_{(t-2,t-1)}$ means that the ESGI has decreased from $t-2$ to $t-1$, representing decreased risk, which can be considered to positively affect an investment in public equity holdings, i.e., an additional investment. To the best of our knowledge, this effect has not been examined in the literature and is the core of our analysis. Research conducted by Wurster and Schlosser (2021) highlights a significant finding that cannot be ignored. The evidence they uncovered indicates that SWFs investment in public equity holdings has a profound impact on the decisions made by other investors. The power that SWFs wield in corporate decision-making and resource deployment causes significant changes in the holdings of other investors year by year.

The *Overall ESG Corporate Social Responsibility* by one lag, ESGR_{t-1}, tells us about ESG ratings that are to a large extend based on company self-reported CSR information and published in CSR reports. The LSEG database (former Refinitiv) defines the ESGR score as an overall company evaluation based on publicly available company self-reported information (LSEG, 2024). According to LSEG, the main sources of information are annual reports, company websites, stock exchange filings, CSR reports, NGO websites, and news sources (LSEG, 2024). The score measures three categories Environmental, Social, and Governance, all of which are intended to generate long-term shareholder value. We will use ESGR as a metric of a company's sustainability performance. The ESGR scores range from 0 (lowest) to 100 (highest).

Tab. 6 shows the LSEG ESG Scores including score ranges, quartiles, and description.

Liang and Renneboog (2020) provide compelling evidence that SWFs consider ESGR factors when taking ownership stakes in listed companies, and they consider the level of past ESGR performance as well as recent ESGR score improvement when making investment decisions. Moreover, the study identifies a positive relationship between SWFs' ESGR considerations and target firms' ESGR performance, suggesting that the integration of ESGR factors could result in better ESGR performance for target firms. These findings demonstrate the need for SWFs to prioritize ESGR considerations in investment decisions. The findings suggest that SWFs with a clear ESG policy or those that prioritize transparency are more likely to incorporate ESGR factors into their investment decisions. Additionally, SWFs originating from developed countries, or countries with civil law origins, tend to place higher importance on ESGR considerations. However, the study did not find significant changes in ESGR scores for firms with SWF ownership stakes, based on analysis of two scandal cases.

Tab. 5: Description of variables and summary statistics

Variable	Code	Description	Mean	Median	Maximum	Minimum	Skewness	Kurtosis	Standard Deviation	Number of Observations	Source
Investor's Holdings	Y	Number of shares held as of the report date (split adjusted as of feed date)	8,713,589.07	0.00	2,760,000,000.00	0.00	17.06	392.24	73,715,363.04	16,520	Refinitiv/LSEG
ESG Corporate Social Irresponsibility	ESGI_{t-1}	Company's risk exposure (by one lag)	11.38	1.00	80.00	0.00	1.40	1.86	14.71	16,520	RepRisk (RRI)
Change in ESGI	$\text{DESGI}_{(t-2,t-1)}$	Change in the company's risk exposure; ESGI per year; calculated by the difference between the lagged values $(t-2)$ and $(t-1)$	0.64	0.00	67.00	−42.00	−2.00	13.71	10.13	14,160	RepRisk (RRI)
Overall ESG Corporate Social Respon-sibility	ESGR_{t-1}	Overall company ESG score based on company self-reported CSR information in the environment (by one lag)	32.56	30.90	94.92	0.00	0.31	−1.28	29.57	16,518	Refinitiv/LSEG
Change in ESGR	$\text{DESGR}_{(t-2,t-1)}$	Change in the company's ESG figure; ESGR per year; calculated by the difference between the lagged values $(t-2)$ and $(t-1)$	0.00	0.00	88.83	−94.11	−2.00	13.70	14.60	16,518	Refinitiv/LSEG
Company Market Capitalisation	CAP_{t-1}	Value of company's market capitalisation (by one lag)	9.11	9.78	14.92	0.00	−2.39	4.89	2.96	16,520	Refinitiv/LSEG
Dividend Yield	DIV_{t-1}	The annual dividend per share divided by the stock's price per share (by one lag)	1.59	0.92	167.42	0.00	27.37	1,449.58	2.88	16,520	Refinitiv/LSEG
Sales Growth	SG_{t-1}	Growth of sales (by one lag)	602.53	4.78	6,423,450.00	−139.40	107.90	12,268.63	54,239.43	16,520	Refinitiv/LSEG
Return on Assets	ROA_{t-1}	Net income divided by total assets (by one lag)	3.96	3.71	2,709.44	−1,352.71	41.37	3,992.73	31.27	16,519	Refinitiv/LSEG
Return on Equity	ROE_{t-1}	Net income divided by shareholder equity (by one lag)	5.89	10.90	12,159.90	−7,988.45	−2.09	814.41	246.55	16,519	Refinitiv/LSEG
Market to Book Ratio	MTB_{t-1}	Market capitalisation divided by total book value (by one lag)	2.28	1.96	896.78	−1,111.26	−26.29	1,037.86	29.39	16,520	Refinitiv/LSEG

Sources: Refinitiv/LSEG, RepRisk

Tab. 6: LSEG ESG Scores

Score range	Quartile	Description
0 to 25	First Quartile	Scores within this range indicates poor relative ESG performance and insufficient degree of transparency in reporting material ESG data publicly.
> 25 to 50	Second Quartile	Scores within this range indicates satisfactory relative ESG performance and moderate degree of transparency in reporting material ESG data publicly.
> 50 to 75	Third Quartile	Scores within this range indicates good relative ESG performance and above average degree of transparency in reporting material ESG data publicly.
> 75 to 100	Fourth Quartile	Score within this range indicates excellent relative ESG performance and high degree of transparency in reporting material ESG data publicly.

Sources: LSEG (2024)

The change in ESG CSR represented by the *Difference in ESG CSR*, $\text{DESGR}_{(t-2,t-1)}$, tells us about the annual change in the company's ESGR, calculated as the difference between the lagged values $t-1$ and $t-2$. The $\text{DESGR}_{(t-2,t-1)}$ can be positive or negative. A positive $\text{DESGR}_{(t-2,t-1)}$ means that the ESGR has grown from $t-2$ to $t-1$, and a higher ESGI means a better ESG factor according to LSEG ESG Scores as outlined in Tab. 6. A negative $\text{DESGI}_{(t-2,t-1)}$ means that the ESGI has decreased from $t-2$ to $t-1$, representing a lower ESG factor.

The *Company Market Capitalization* by one lag, CAP_{t-1}, refers to the value of a company's market capitalization. It serves as an indicator for SWF investment in public equity holdings. Market capitalization plays a role in investment decision making overall. Investors often rely on market capitalization to gauge the size of a company and determine whether it falls under cap mid cap or small cap stocks. Different investors may prefer investing in companies of varying sizes depending on their investment objectives risk tolerance and strategies (Wagner, 2013). Companies that are included in these indexes benefit from increased visibility and credibility, which can lead to increased investor interest and demand for their stock. As most SWFs invest in market indices, it is unrealistic to broadly exclude market index companies from their portfolios. Liang and Renneboog (2020) find no clear evidence for a positive relation between CAP and ownership. In some cases, this relationship is positive, but in some negative, depending on the econometric model chosen (the Hackman Model and the Probit Panel Random-Effects Model).

The *Dividend Yield* by one lag, DIV_{t-1}, refers to the dividend per share divided by the price per share of the stock. Considering DIV is crucial when making investment choices. DIV represents the portion of a company's stock price that is distributed to shareholders as dividends. Stocks that pay dividends can offer investors an income stream which is important for those seeking to generate income like retirees. DIV also serves as an indicator of a company's return on investment (ROI) for shareholders. A higher dividend yield indicates a return on investment which appeals to investors seeking returns. A company's capability to distribute dividends consistently and maintain a dividend yield indicates its wellbeing. When companies regularly pay dividends it usually signifies that they have a cash flow, robust earnings, and a long-term growth strategy. This makes them more appealing as investment options. Dividend paying stocks are often considered suitable for long-term investments due to the stability and predictability of dividend payments. These payments provide investors with a sense of security. According to Liang and Renneboog's study in 2020, there is evidence suggesting that higher levels of equity holdings dividends influence the ownership stakes of SWFs in these companies.

The *Sales Growth* by one lag, SG_{t-1}, refers to the ratio of dividend per share to the price per share of a stock. It serves as an indicator of a company's revenue generation capability. When sales increase it signifies that there is demand for the company's products or

services which can lead to profits and a positive outlook for its performance. Additionally, SG can also indicate a company's ability to gain market share. If a company can boost its sales in a market it may be gaining market share from its competitors, which is seen as a sign for investors. Furthermore, SG offers insights into a company's growth potential. Companies that consistently demonstrate sales growth over time may have an edge in the market and possess robust growth strategies making them potentially attractive investment opportunities. SG can also be an indicator of broader industry trends. If a company's sales are increasing in an industry that is also experiencing growth, it may be an indication that the company is well-positioned to capitalize on industry trends. Liang and Renneboog (2020) find positive evidence that SG influences SWF ownership of these companies. Wurster and Schlosser (2021) reveal that a rise in ownership by SWFs leads to a decline in market value, operating performance, and investment efficiency of target companies. These results align with the viewpoints presented by Bortolotti et al. (2015), which propose the political agenda hypothesis and passive investor hypothesis. According to these theories, SWF investments in target companies are linked to declining performance and sales growth in the subsequent three years. Additionally, having a SWF on the board of directors is linked to more significant SWF discounts, ultimately having an adverse effect on firm value. Bortolotti et al. (2015) found that the median SG of SWF equity investments was lower than the SG of a benchmark sample.

The *Return on Assets* by one lag, ROA_{t-1}, which is calculated by dividing a company's net income by its total assets, is widely regarded as a critical indicator used to determine whether to invest in public equity holdings. This measure is considered a valuable predictor that helps to make informed investment decisions. ROA gauges a company's efficiency in generating profits relative to its assets, which can be a sign of management competence. Liang and Renneboog (2020) find positive evidence that ROA influences SWF ownership. This theory is supported by empirical findings of Bortolotti et al. (2015), who found that the median ROA of SWF equity investments is higher than the ROA of a benchmark sample.

The *Return on Equity* by one lag, ROE_{t-1}, is a financial metric of a company's net income in relation to its shareholder equity, and it is a vital predictor used by SWFs to evaluate the potential gains of investing in public equity holdings. This metric helps to make informed investment decisions by providing insights into a company's profitability and overall financial health. Like ROA, ROE can be used to compare a company's performance to its peers in the same industry. Companies with a higher ROE may have a competitive advantage or a more efficient business model, which can make them a more attractive investment option. A higher ROE can also imply a higher return on investment for shareholders. Liang and Renneboog (2020) find positive evidence that ROE influences SWF ownership of these companies.

Finally, the *Market to Book Ratio* by one lag, MTB_{t-1}, is a measure used to guide investment decisions in traded companies. It compares a company's market value to its book value which represents the worth of its assets after subtracting liabilities. Assessing the MTB ratio helps determine if a company is undervalued or overvalued. A lower MTB ratio indicates undervaluation presenting an investment opportunity while a higher MTB ratio suggests overvaluation and may not be an investment option. Furthermore, analyzing the MTB ratio provides insights into a company's growth potential. A lower MTB ratio could indicate that the market has yet to recognize the growth prospects of a company whereas a higher MTB ratio might imply that the market has already factored in its growth potential. According to Liang and Renneboog (2020) there is no evidence supporting any correlation between SWFs ownership of public equity holdings and the MTB ratio. In fact, depending on the model used (such as the Hackman Model or Probit Panel Random Effects Model) this relationship can exhibit tendencies. Bortolotti et al. (2015) found that the median MTB of SWF equity investments was higher than the MTB of a benchmark sample.

3.3.2 Model Specification

The relationship between equity holding investment and explanatory factors was investigated with the application of a logit model in Eq. 1.

$$\begin{aligned}\ln\left(\frac{p_i}{1-p_i}\right) = \beta_0 &+ \beta_1\,\mathrm{ESGI}_{t-1} + \\ &+ \beta_2\,\mathrm{DESGI}_{(t-2,t-1)} + \\ &+ \beta_3\,\mathrm{ESGR}_{t-1} + \\ &+ \beta_4\,\mathrm{DESGR}_{(t-2,t-1)} + \\ &+ \beta_5\,\mathrm{CAP}_{t-1} + \\ &+ \beta_6\,\mathrm{DIV}_{t-1} + \\ &+ \beta_7\,\mathrm{SG}_{t-1} + \\ &+ \beta_8\,\mathrm{ROA}_{t-1} + \\ &+ \beta_9\,\mathrm{ROE}_{t-1} + \\ &+ \beta_{10}\,\mathrm{MTB}_{t-1}\end{aligned} \tag{1}$$

The model was estimated with the binary dependent variable $Y = 1$ if an investment took place or $Y = 0$ if there was no change in the equity holding position or disinvestment. Explanatory variables used in the model are described in Tab. 6. The model was optimized using a stepwise backward elimination method whereas the initial model included all variables. The least significant variable was consequently eliminated in every next step. The results interpreted in this paper include the conclusion of the backward elimination with significant variables only. Variable DESGI was left in the model despite its insignificance because the influence of this variable was subject to the conducted analysis. Model parameters were estimated with Fisher scoring method which is equivalent to iteratively reweighted least squares. To obtain robust estimates and reduce possible bias was applied bias-reducing penalized maximum likelihood fit. Pre-analysis included also diagnostic test to check for the correlation across explanatory variables (Tab. 7), but no significant correlations were found.

The relationship between the estimated coefficients and probability of equity holding investment was not linear and was obtained using formula:

$$p_i = \frac{1}{1+\mathrm{e}^{-x}},$$

where

$$\begin{aligned}x = \beta_0 &+ \beta_1\,\mathrm{ESGI}_{t-1} + \beta_2\,\mathrm{DESGI}_{(t-2,t-1)} + \\ &+ \beta_3\,\mathrm{ESGR}_{t-1} + \beta_4\,\mathrm{DESGR}_{(t-2,t-1)} + \\ &+ \beta_5\,\mathrm{CAP}_{t-1} + \beta_6\,\mathrm{DIV}_{t-1} + \beta_7\,\mathrm{SG}_{t-1} + \\ &+ \beta_8\,\mathrm{ROA}_{t-1} + \beta_9\,\mathrm{ROE}_{t-1} + \beta_{10}\,\mathrm{MTB}_{t-1}\end{aligned}$$

The estimated probability was used to verify the prediction ability of the model. If the predicted probability was smaller than 0.5 it was considered as predicted 0. If the predicted probability was 0.5 and higher it was considered as predicted 1. The explanatory power of the model was expressed as the number of concordant and discordant predictions in comparison with real-world data. The global hypothesis about the overall significance of the model was verified using the likelihood ratio and Wald criteria.

In the results, the odds ratios were interpreted instead of the estimated model parameters as they were linearly related with odds and were derived from the model parameters according to Eq. 2.

$$\text{odds ratio} = \frac{\text{odds}\,(x_j+1)}{\text{odds}\,(x_j)} = \mathrm{e}^{\beta_j} \tag{2}$$

The interpretation is that odds in favor of purchase multiply by e^{β_j} with each unit increase of x_j. Interval estimate for odds ratio was based on Wald confidence limits.

3.3.3 Limitations

This study comes with some limitations. First, we focused on scandal case industry holdings and did not consider the full portfolio of public equity holdings of the selected SWFs. We deem this a minor problem as we concentrated on the main industries from a CSI point of view (e.g., automobile, oil and gas, chemicals, and food and beverage). Nevertheless, it might have been beneficial to evaluate the full portfolio to give a holistic answer to our main research questions and to add more industry perspectives. Second, we concentrated on SWFs both with an appropriate number of public equity holdings that can be analysed and that invested in scandal case holdings. In most cases, other liquid (e.g., fixed income) and espe-

Tab. 7: Pearson Correlation Coefficients, Prob > $|r|$ under $H_0 : \rho = 0$

	ESGI$_{t-1}$	**DESGI$_{t-1}$**	**ESGR$_{t-1}$**	**DESGR$_{t-1}$**	**CAP$_{t-1}$**	**DIV$_{t-1}$**	**ROA$_{t-1}$**	**MTB$_{t-1}$**	**ROE$_{t-1}$**	**SGT$_{t-1}$**
ESGI$_{t-1}$	1.0000	0.0966***	0.5618***	0.0879***	0.2998***	0.1711***	0.0084	−0.0281***	0.0097	0.0173**
		< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	0.2791	0.0003	0.2100	0.0254
DESGI$_{t-1}$	0.0966***	1.0000	0.0002	0.0114	0.0081	0.0078	−0.0049	0.0069	0.0149	0.0030
	< 0.0001		0.9727	0.1741	0.3323	0.3523	0.5619	0.4101	0.0764	0.7182
ESGR$_{t-1}$	0.5619***	0.0003	1.0000	0.2472***	0.4167***	0.2224***	0.0261***	−0.0159**	0.0442***	0.0176**
	< 0.0001	0.9727		< 0.0001	< 0.0001	< 0.0001	0.0008	0.0406	< 0.0001	0.0234
DESGR$_{t-1}$	0.0879***	0.0114	0.2472***	1.0000	0.1381***	0.0014	0.0220***	−0.0126	0.0036	0.0067
	< 0.0001	0.1741	< 0.0001		< 0.0001	0.8583	0.0047	0.1052	0.6416	0.3884
CAP$_{t-1}$	0.2998***	0.0082	0.4167***	0.1381***	1.0000	0.1756***	0.0720***	0.0216***	0.0227***	−0.0269***
	< 0.0001	0.3323	< 0.0001	< 0.0001		< 0.0001	< 0.0001	0.0054	0.0035	0.0005
DIV$_{t-1}$	0.1712***	0.0078	0.2224***	0.0014	0.1756***	1.0000	0.0333***	−0.0032	0.0198**	0.0006
	< 0.0001	0.3523	< 0.0001	0.8583	< 0.0001		< 0.0001	0.6855	0.0111	0.9424
ROA$_{t-1}$	0.0084	−0.0049	0.0261***	0.0220***	0.0720***	0.0333***	1.0000	−0.0022	0.0765***	−0.0044
	0.2791	0.5619	0.0008	0.0047	< 0.0001	< 0.0001		0.7783	< 0.0001	0.5731
MTB$_{t-1}$	−0.0281***	0.0069	−0.0159**	−0.0126	0.0216***	−0.0032	−0.0022	1.0000	0.0464***	−0.0018
	0.0003	0.4101	0.0406	0.1052	0.0054	0.6855	0.7783		< 0.0001	0.8131
ROE$_{t-1}$	0.0098	0.0149*	0.0442***	0.0036	0.0227***	0.0198**	0.0765	0.0464***	1.0000	0.0006
	0.2100	0.0764	< 0.0001	0.6416	0.0035	0.0111	< 0.0001	< 0.0001		0.9436
SGT$_{t-1}$	0.0174**	0.0030	0.0176**	0.0067	−0.0269***	0.0006	−0.0044	−0.0018	0.0006	1.0000
	0.0254	0.7182	0.0234	0.3884	0.0005	0.9424	0.5731	0.8131	0.9436	

Note: statistical significance at $\alpha = 0.001$ (***), $\alpha = 0.05$ (**), $\alpha = 0.1$ (*) level.
Sources: SAS output on Refinitiv/LSEG and RepRisk data

cially illiquid/private market investments (e.g., private equity and infrastructure) by SWFs are currently undisclosed and non-transparent (Déséglise and Freijido, 2019; Fotak et al., 2016; Gangi et al., 2019). It is important to mention that we could have used alternative models and setups. However, these may have resulted in certain disadvantages. For instance, we could reduce our sample size to avoid missing values for some of our independent variables. This could potentially produce stronger results, but the number of observations would have been significantly lower. Finally, we did not use dynamic models in our analysis, which means we did not include the lagged values of the endogenous variable.

4 RESULTS AND DISCUSSION

The model suggests that the purchase of stocks is significantly influenced by variables ESGI$_{t-1}$, ESGR$_{t-1}$, CAP$_{t-1}$, DIV$_{t-1}$, ROA$_{t-1}$, and MTB$_{t-1}$ (Tab. 8). The overall significance of the logit model was verified by the likelihood ratio and Wald test, both with p-value < 0.0001, which means that the model is significant. The explanatory power of the model was evaluated by the number of concordant predictions which were equal to 66.1%. The results suggest that the variable that most influences the purchase of a stock is CAP$_{t-1}$. For every unit increase in CAP$_{t-1}$, the odds in favor of stock purchase rise by 15%. The estimated influence of CAP$_{t-1}$ on odds is between 12.8% and 17.2%. The second most influential variable, according to the odds ratio estimates, is DIV$_{t-1}$, which for each unit increase the odds in favor of stock purchase rise by 2.8%. The estimated influence on odds is between 0.9% and 4.7%. The third most influential variable, according to the odds ratio estimates is ESGR$_{t-1}$, which for each unit increase the odds in favor of stock purchase rise by 1.1%. The estimated influence on odds is between 0.9% and 1.2%. The influence of other variables on the purchase of a stock is smaller: ESGI$_{t-1}$ by 0.9%, ROA$_{t-1}$ by 0.3%,

Tab. 8: Model results

Variable	Coefficient	Standard Error	Wald Chi-Square	Pr > ChiSq	Odds ratio point estimate	95% Wald Confidence Limits	
Intercept	−2.175***	0.089	591.800	< 0.001	–		
$ESGI_{t-1}$	0.009***	0.001	40.780	< 0.001	1.009	1.007	1.012
$ESGR_{t-1}$	0.010***	0.001	204.560	< 0.001	1.011	1.009	1.012
CAP_{t-1}	0.139***	0.0100	204.610	< 0.001	1.150	1.128	1.172
DIV_{t-1}	0.027***	0.009	8.570	0.003	1.028	1.009	1.047
ROA_{t-1}	0.003**	0.001	4.910	0.027	1.003	1.000	1.005
MTB_{t-1}	0.001**	0.001	4.090	0.043	1.001	1.000	1.002
$DESGI_{(t-2,t-1)}$	0.001	0.002	0.350	0.553	1.001	0.998	1.004
$DESGR_{(t-2,t-1)}$	0.005	0.002	0.056	0.813	1.000	0.996	1.005

Note: statistical significance at $\alpha = 0.001$ (***), $\alpha = 0.05$ (**), $\alpha = 0.1$ (*) level.
Sources: SAS output on Refinitiv/LSEG and RepRisk data

and MTB_{t-1} by 0.1%. The estimated odds ratios and their confidence limits are compared in Tab. 8.

The variables ROE_{t-1}, $DESGR_{(t-2,t-1)}$, $DESGI_{(t-2,t-1)}$, SG_{t-1}, and were eliminated from the model as insignificant, i.e., not significantly affecting the probability of stock purchase. Fig. 1 shows the comparison of $DESGI_{(t-2,t-1)}$ distribution in both categories of the dependent variable. The plots show maximum and minimum values, and the box is created by the 1st and 3rd quartile. Values outside the minimum and maximum can be considered outliers. The average and median $DESGI_{(t-2,t-1)}$ are similar in both categories. Hence, there is no significant difference in $DESGI_{(t-2,t-1)}$ of the compared categories. This implies that $DESGI_{(t-2,t-1)}$ does not significantly affect the binary dependent variable. This was confirmed also by results from the estimated logit model.

According to applied logit regression to create predictive model, Tab. 9 provides information on the post-hoc test of the final model in terms of, e.g., predictive accuracy, sensitivity, and specificity.

Tab. 9: Association of Predicted Probabilities and Observed Responses

Percent Concordant	66.1	Somers' D	0.323
Percent Discordant	33.8	Gamma	0.323
Percent Tied	0.0	Tau-a	0.158
Pairs	49053400	c	0.661

Sources: SAS output on Refinitiv/LSEG and RepRisk data

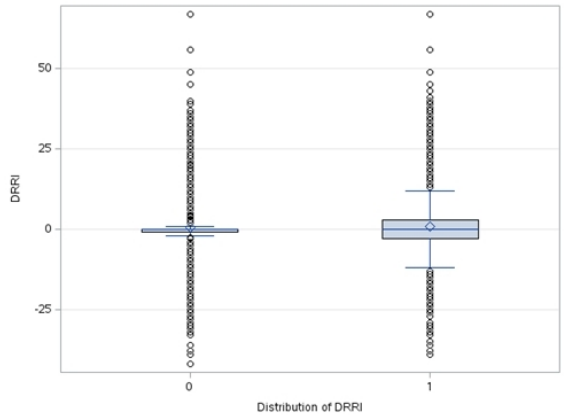

Fig. 1: Boxplot comparison of $DESGI_{(t-2,t-1)}$ in the 0 and 1 categories of Y
Sources: SAS output on Refinitiv/LSEG and RepRisk data

In our data set, CAP_{t-1} plays a more important role than $ESGR_{t-1}$ for SWF investment decision-making. This contrasts with Liang and Renneboog (2020), who find no clear evidence for a positive relationship between CAP_{t-1} and ownership. In some of their analyzed cases, this relationship is positive but in some it is negative, depending on the econometric model chosen. The difference in significance of company market capitalization may depend on the scope of industries chosen. Our data set concentrates on industries selected from former reputational risk scandal cases. Furthermore, our results are consistent with the findings of Liang and Renneboog (2020) for DIV_{t-1}. They find that a higher DIV_{t-1} of public equity holdings influences the ownership decisions of SWFs. In our data set, DIV_{t-1} plays an important role for the investment decision. The annual dividend per share paid has a signal effect for the capital strength of a company, especially for those investors who have a broad and diversified equity portfolio. In addition, Liang and Renneboog (2020) find positive evidence that ROA_{t-1} influences SWF ownership decisions. This theory is supported by the empirical findings of Bortolotti et al. (2015), who found that the median ROA of SWF equity investments was higher than the ROA of a benchmark sample. The results of our sample show that the purchase of stocks is significantly influenced by ROA_{t-1}. Furthermore, Liang and Renneboog (2020) find no clear evidence for a positive relationship between MTB and ownership. In some cases, this relation is positive but in some also negative, again depending on the econometric model chosen. Bortolotti et al. (2015) found that the median MTB of SWF equity investments was higher than the MTB of a benchmark sample. Our results show that there is a positive relationship between MTB_{t-1} and stock ownership. It seems that for the scandal case data set chosen for our analysis, SWFs see a value in MTB_{t-1} for the market valuation and growth potential of related public equity holdings. In contrast to the findings of Liang and Renneboog (2020) for SG_{t-1} and ROE_{t-1}, as well as Bortolotti et al. (2015) for SG, the variables SG_{t-1} and ROE_{t-1} were eliminated from our model as insignificant, i.e., they do not significantly affect the probability of stock purchase. This may be a result of the different scope and focus of our analysis.

Our findings related to Corporate Social Responsibility support earlier research showing a trend among SWFs to consider ESG practices of their portfolio companies when making investment decisions using ESG data that is to a large extend company self-reported (Liang and Renneboog, 2020). The model results show that $ESGR_{t-1}$ is statistically significant on an $\alpha = 0.01$ level. For every unit increase in $ESGR_{t-1}$, the odds in favour of stock purchase rise by 1.1%. The estimated influence of $ESGR_{t-1}$ on odds is between 0.9% and 1.2%. However, the coefficient for $ESGR_{t-1}$ is lower than those of CAP_{t-1} and DIV_{t-1} as both are the most dominant variables related to a purchase of public equity holdings by SWFs in scope of this analysis.

Our results regarding the consideration of Corporate Social Irresponsibility measures revealed by the media are various and need to be separated between last available ESG CSI data, $ESGI_{t-1}$, and past changes in ESG CSI data from $t-2$ to $t-1$, $DESGI_{(t-2,t-1)}$.

Regarding $ESGI_{t-1}$, the results show that $ESGI_{t-1}$ is statistically significant on an $\alpha = 0.01$ level. For every unit increase in $ESGI_{t-1}$, the odds in favour of stock purchase rise by 0.9%. The estimated influence of $ESGI_{t-1}$ on odds is between 0.7% and 1.2%. However, the coefficient of $ESGI_{t-1}$ is lower than the coefficient of $ESGR_{t-1}$ which means that company self-reported ESG CSR data has more influence on the purchase of public equity holdings of SWFs than negative reputation risk ESG CSI data purely derived from independent sources. In addition, the standard deviation of $ESGI_{t-1}$ is higher than for $ESGR_{t-1}$. It seems obvious that SWFs still consider company self-reported CSR information (ESGR) more than public CSI data (ESGI), including changes in reputation risk (DESGI), in their investment decisions regarding public equity holdings. However, this may just be a timing effect. Some years ago, SWFs started to include

ESG data based on self-reported information in their investment decision-making process for sustainability reasons. Farag et al. (2022) examined the effect of SWFs on corporate ESG reputation risk. Their research uncovered a significant positive impact of SWF ownership on the reputation risk associated with ESG factors. Their results are in accordance with the theories on the effect of institutional investors' ownership on firm ESG reputation risk. To expand their corporate governance framework, SWFs in turn may take the opportunity to look closely at reputation risk figures tracked from media coverage of incidents influencing the ESG performance of firms. What we cannot read from the data is if this effect is the same (1) for every ESGI range (from 0 to 100; Tab. 4), (2) for corresponding risk exposure (from low risk to extremely high risk; Tab. 4), and (3) for a switch of one ESGI range and corresponding risk exposure to another.

$\text{DESGI}_{(t-2,t-1)}$ and $\text{DESGR}_{(t-2,t-1)}$ were eliminated from the model as insignificant and therefore do not significantly affect the probability of stock purchase. Both are defined as past changes of ESG data from $t-2$ to $t-1$, $\text{DESGI}_{(t-2,t-1)}$ for Corporate Social Irresponsibility and $\text{DESGR}_{(t-2,t-1)}$ for Corporate Social Responsibility. Hence, a change in past ESG data of underlying public equity holdings does not seem to have a significant effect on an investment into the underlying holding – at least within the scope of this analysis. This is an interesting observation as SWF take past ESG data into account when deciding for a purchase into public equity holdings but may not consider past changes in ESG data on a statistically significant level.

Question is, if this is because financial company data are still a predominant reason for a purchase or – even worse – is it because SWFs just go the half mile in "walking the talk" on ESG matters? We will not be able to completely answer these questions here but would instead rather open the academical discussion. While the one group of SWFs like KIC from Korea, GPFG from Norway, and CIC from China have the highest ESG evaluation scores the SWFs group around ADIA from UAE, SAMA from Saudia Arabia, and NSSF from China have the lowest. Hence, ESG behaviour very much depends on what scope of investors is in focus of the analysis. Some may just be equity investors to make money and to maximize the return of their investments.

Based on the summary of empirical analysis, H_1 null "There is no influence of public equity holding Corporate Social Irresponsibility data on the investment decision of SWFs regarding public equity holdings." can be rejected. Hypothesis 1 is accepted which means that "Public equity holding Corporate Social Irresponsibility data has a pronounced influence on the investment decision of SWFs". Additionally, H_2 null "The influence of public equity holding Corporate Social Irresponsibility data on the investment decision of SWFs is higher than the influence of company self-reported CSR information." can be rejected. Hypothesis 2 is accepted which means that "The influence of public equity holding Corporate Social Irresponsibility data on the investment decision of SWFs is not higher than the influence of company self-reported CSR information". The research question "Are SWF sensitive to ESG CSI data when considering an investment in public equity holdings?" can be affirmed.

5 CONCLUSIONS AND OUTLOOK

SWFs are some of the most significant and formidable global institutional investors, along with pension funds and insurance companies. Although their investment behavior has been subjected to numerous research studies, their individual investment decisions across various asset classes remain mostly obscure. Nonetheless, their substantial influence on the sustainability of economies cannot be ignored, as SWFs significantly impact the corporate landscape and social welfare (Capapé, 2018). The inquiry at hand pertains to the level

of concern exhibited by SWFs regarding the sustainability of their investments and the underlying factors that drive their responsible behavior. Our research contributes to the literature on the impact of CSI factors on the investment decision-making process of SWFs, particularly in relation to their investments in publicly traded equity holdings. To measure the CSI associated with individual firms, we utilized an objective indicator based on external evaluations of the target companies. Specifically, we employed the RepRisk dataset, which monitors media coverage of incidents affecting the ESG performance of firms.

It appears evident that SWFs still prioritize company self-reported CSR information over publicly available independent CSI data expressed by reputation risk figures in their investment decision-making process concerning publicly traded equity holdings. If this turns out to be true, there is need for a greater ESG integration into SWF investment strategies and call for a promotion of sustainable investing practices not limited to liquid assets to showcase a sustainable "walk the talk". However, this may simply be a matter of timing. In previous years, SWFs began incorporating ESG data derived from self-reported information into their investment decision-making process due to sustainability considerations. Thus, we suggest that SWFs and other investors incorporate external CSI indicators as a preliminary measure for present and future investments. This explicitly includes the recommendation to also make use of past changes to ESG CSI data regarding a change in reputation risk. This approach should be expanded to include not only publicly traded equity holdings but also other liquid investments such as fixed income securities, as well as illiquid investments such as private equity and infrastructure. Notably, these types of investments are often undisclosed and non-transparent, yet increasingly feature sustainability elements and labels, making the inclusion of external CSI indicators particularly important. The analysis of SWF investment behavior in relation to ESG assets provides important insights into their investment strategies and decision-making processes. The results of our study suggest that SWFs are increasingly considering ESG factors when making investment decisions, but there is still room for improvement. Policymakers and stakeholders can use these findings to encourage greater ESG integration in SWF investment strategies and promote sustainable investing practices more broadly.

This study comes with some limitations. First, we focused on scandal case industry holdings and did not consider the full portfolio of public equity holdings of the selected SWFs. We deem this a minor problem as we concentrated on the main industries from a CSI point of view (e.g., automobile, oil and gas, chemicals, and food and beverage). Nevertheless, it might have been beneficial to evaluate the full portfolio to give a holistic answer to our main research questions and to add more industry perspectives. Second, we concentrated on SWFs both with an appropriate number of public equity holdings that can be analyzed and that invested in scandal case holdings. In most cases, other liquid (e.g., fixed income) and especially illiquid/private market investments (e.g., private equity and infrastructure) by SWFs are currently undisclosed and non-transparent (Déséglise and Freijido, 2019; Fotak et al., 2016; Gangi et al., 2019). It is important to mention that we could have used alternative models and setups. However, these may have resulted in certain disadvantages. For instance, we could reduce our sample size to avoid missing values for some of our independent variables. This could potentially produce stronger results, but the number of observations would have been significantly lower. Finally, we did not use dynamic models in our analysis, which means we did not include the lagged values of the endogenous variable.

Our study aimed to contribute to the existing literature while offering a new perspective by adding CSI factors as a main variable for the investment decision of SWFs to invest into public equity holdings. Based on our results, we can offer some suggestions for future research and improvement. Special research should be performed on the sensitivity of the socio-economic environment and financial market

events on the ESG CSI behavior of SWFs. Additionally, a special view could specifically be spent on the influence of ESG CSI and ESG CSR data on the sell-behavior of SWFs related to public equity holdings. We only made use of static models for our analysis. In future research we suggest including the dependent variable as an independent variable with one period lagged to test if the past values of SWF holdings affect the model results. Thus, dynamic models can be used. Specifically, a Generalized Method of Moments (GMM) or Maximum Likelihood (ML) estimator can be used to regress the dynamic panel datasets.

Common holding data, particularly self-reported ESG data, continues to be a significant factor in the investment decision-making process. The transparency of reputation risk changes (positive and negative) should – as a pre-indicator – help decision-makers to enhance sustainability in their portfolios (Hentov and Petrov, 2017; Stone and Truman, 2016). Reputation risks within a portfolio should be avoided due to price effects based on bad reputation risk factors. Hence, in a bad reputation risk scenario, there shouldn't be any investment at all, or an earlier-as-market-sell could help to protect the reputational risk value of a portfolio. To adequately capture the effects of reputation risk, longitudinal studies are needed, which can bridge the gap between scientific research and the practices of individual SWFs as well as initiatives such as the One Planet Initiative, International Forum of Sovereign Wealth Funds, and the Sovereign Wealth Fund Institute. In addition, future studies should analyze investment behavior and CSI factor consideration in relation to concrete profit-and-loss calculation and statistic forecasting balance sheet management. This might also be considered in future research on whether the investment behavior of SWFs is equivalent to that of other major investors, such as insurance companies and public pension schemes (Blundell-Wignall et al., 2008; Boubakri et al., 2016). This should not be limited only to public equity holdings but should also consider additional liquid asset classes, e.g., fixed income and public real estate, as well as private market investment such as infrastructure equity and debt and real estate.

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AUTHOR'S ADDRESS

Marty-Jörn Klein, Faculty of Business and Economics, Mendel University in Brno, Zemědělská 1665/1, 613 00 Brno, Czech Republic, e-mail: marty.klein@gmx.de (corresponding author)

Gabriela Chmelíková, Department of Regional and Business Economics, Faculty of Regional Development and International Studies, Mendel University in Brno, Zemědělská 1, 613 00 Brno, Czech Republic, e-mail: gabriela.chmelikova@mendelu.cz

Jozef Palkovič, Institute of Statistics, Operations Research and Mathematics, Faculty of Economics and Management, Slovak University of Agriculture in Nitra, Tr. A. Hlinku 2, 949 76 Nitra, Slovak Republic, e-mail: jozef.palkovic@uniag.sk

ENHANCING MARKET VALUE ESTIMATION FOR PRIVATELY HELD COMPANIES: DIFFERENTIATED MULTIPLIERS IN THE CZECH BREWING INDUSTRY

Michal Drábek[1]✉, Pavel Syrovátka[1]

[1] *Mendel University in Brno, Czech Republic*

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ABSTRACT

The paper focuses on valuation multipliers for privately held companies, with the aim of developing and applying a methodological procedure to improve the accuracy of estimating the market value. This improvement is achieved through the differentiation of an industry multiplier using financial decomposition. We applied the proposed methodology enhancements to a dataset comprising 50 Czech breweries, estimating their market value using the discounted cash flow method. Importantly, our proposed modification to the methodology is not limited to this sample of breweries; its nature makes it a generally applicable procedure. Our results demonstrate that the application of our proposed procedure significantly enhances the accuracy of market value estimation for privately held companies, yielding an increase of 40–50% compared to the use of the median value.

KEY WORDS

privately held company, valuation, industry multiplier, differentiated multipliers, Czech breweries valuation

JEL CODES

G12, G32

1 INTRODUCTION

During highly volatile times in the stock markets, there is an increasing need to estimate whether a particular stock or even an entire stock index is undervalued or overpriced, which is evident in the number of studies dedicated specifically to crisis periods (e.g. Gandré, 2020; Boubaker et al., 2022; Tzomakas et al., 2023). Estimating the market value of an asset (including companies) generally involves three approaches: income, comparative (relative), and cost approach (IVSC, 2016). When valuing publicly traded companies, the

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relative approach using multipliers is typically the most common and straightforward way to obtain indicative value information and assess potential undervaluation (Damodaran, 2010). However, applying that relative approach to privately held companies presents certain challenges in respect of the different position and risk profile reflected in the presence of a difference in the value multiple (Goetz, 2021). Addressing these challenges and illustrating the appropriate adaptation of the relative valuation approach for privately held companies serve as the primary motivations behind our article. Despite the aforementioned challenges in using this approach, its choice is obvious to the appraisers. In general, the advantage of this valuation approach lies in its simplicity. By using a comparable company's (or industry's) multiplier and the value of a reference variable (such as profit or sales) of Company X, one can assess the market value of Company X. This approach is also useful for comparing companies within an industry. One widely used multiplier is the P/E ratio, which is the product of the market price per share (P) and net earnings per share (E). However, there are various valuation multipliers used in the relative valuation approach, such as the market price per share to sales per share (P/S) ratio or the market price per share to book value of equity per share (P/BV) ratio. Additionally, there are other multipliers based on enterprise value (i.e., the gross operational value of the company) related to relevant variables like sales, EBIT, EBITDA, and more (the multiples are generally divided into two groups: Equity- and Entity-based – see e.g. Nel et al., 2013)

As mentioned earlier, employing the relative valuation approach for privately held companies necessitates certain additional adjustments to the conventional company valuation methodology. Although the option to utilize multipliers derived from the publicly traded company sector is available, this approach may introduce biases due to disparities in risk, liquidity, and other factors between the stocks of these two company types (see Chen et al., 2015). It is naturally more appropriate for these companies to employ multipliers directly derived from data sourced from privately held companies. However, such data is often inaccessible. A method for acquiring these specific multipliers, particularly within the Czech brewing industry, is demonstrated in papers such as Drábek (2022). Yet, a significant drawback of this approach is the initial necessity to evaluate the market value of numerous privately held companies, which is a time-consuming and challenging task.

Focusing on the meticulous adjustments and enhancements of the multiplier approach holds substantial potential. This is because it can lead to more precise estimates of the market value of the privately held companies. Furthermore, the relative (market) valuation approach is preferred by valuation standards (IVSC, 2016), even though it is a less accurate method in general (Fernández, 2002). A refinement of the relative valuation approach would also yield more realistic outcomes when comparing companies within the industry or its segments. These enhancements within the relative valuation approach – the multiplier methodology – would not only be advantageous to the entities and stakeholders themselves but would also prove invaluable in valuing companies mandated by various legal regulations, such as expert opinions in instances of squeeze-outs.

In this paper, we advance the development of a methodology aimed at deriving differentiated multipliers tailored for private company valuations. Our focus is on utilizing publicly available data concerning industry multipliers sourced from publicly traded companies. This data can be sourced from fee-based databases (such as Refinitiv Eikon, Bloomberg) or publicly accessible sources (e.g., Damodaran, 2020 and 2021). However, in order to utilize these multiples for valuing privately held companies, they need to be appropriately adjusted. One approach for adjustment is the inclusion of a so-called private company discount (more details can be found in the Section 2).

Despite these adjustments, the valuation multipliers still remain at an aggregate level. The value of the valuation multiplier is established within the broader context of all companies within the industry. While an ag-

gregate multiplier, whether represented as an industry average or median, imparts valuable valuation insights for a given industry, it may not accurately capture the intricacies of a specific privately held company. It is worth adding, however, that according to Dittmann and Maug (2008), the median and the geometric mean are unbiased while the arithmetic mean is biased upward as much as the harmonic mean is biased downward (based on logarithmic errors implications).

Hence, this paper proceeds to refine differentiated estimates of valuation multipliers designed for private companies within a targeted industry. The unique financial attributes of the subject company are employed to differentiate these multiplier estimates. The primary aim of this differentiation lies in achieving reduced deviations in the valuation of the particular company, compared to using the standard industry multiplier in its average or median form.

Building on the aforementioned contexts, this article centers on enhancing and expanding the application of the methodology involving differentiated industry multipliers. This refined approach can then be harnessed more effectively in the relative valuation of companies within a specific industry. In this regard, our paper builds upon the previous research (Drábek and Syrovátka, 2022) that focused on differentiating estimates of the industry P/BV ratio for privately held companies in the Czech brewing industry. In that study, authors differentiated the industry multiplier using the P/EAT ratio and return on equity (ROE), as well as the P/EAT ratio, return on assets (ROA), and financial leverage (FL). The significant effect of differences in companies' financial characteristics on the value of the multiplier is also confirmed by the results of Henschke and Homburg (2009).

Based on the aforementioned background, the objective of this paper is to develop and apply a methodological procedure for valuing privately held companies, specifically within the Czech brewing industry, by differentiating estimates of the industry P/BV multiplier. This differentiation will be achieved through the decomposition of the P/BV multiplier into P/EAT, ROA, and FL (where "P" represents the market value of equity and "EAT" refers to earnings after taxation). The proposed methodology upgrade also incorporates the application of a private company discount (PCD), which allows for a broader and more general application of the methodology by incorporating multiples derived from publicly traded company data into the valuation of privately held companies. Additionally, the inclusion of PCD within this methodology significantly streamlines the initial calculation phase for privately held companies.

In comprehensive practical testing of the proposed valuation methodology through the lens of differentiated industry multipliers, the results were ascertained for companies operating within the Czech brewing industry in 2019. Subsequently, the same valuation methodology was applied to these companies in the subsequent year, 2020. The obtained results were then compared, and the pertinent deviations were determined and assessed as indicators of "valuation accuracy."

Aligned with the aforementioned objectives, this article encompasses two significant contributions. Firstly, we introduce an enhancement to the existing valuation methodology through the incorporation of a differentiated industry multiplier. This improvement is rooted in the decomposition of the P/BV ratio, with particular attention to the application of discounts for private companies. Secondly, we test this methodology using a specific dataset spanning the years 2019 and 2020. Within this assessment, we determine the multiplier values applicable to the valuation of privately held companies. Additionally, we undertake an evaluation and analysis of the observed deviations arising from the application of both differentiated and non-differentiated multipliers.

Our findings demonstrate that the application of our proposed procedure significantly enhances the accuracy of market value estimation for privately held companies, with an average increase ranging from 20% to 80% compared to using the aggregate value for the industry, and a

40–50% increase compared to using the median value.

The paper is structured as follows: Section 2 presents the literature review of relevant studies. Section 3 provides an overview of the data and methods employed. Section 4 presents the results of our analysis. The robustness of our findings is examined in Section 5, while Section 6 discusses the results in relation to other studies and the applicability of our findings. Finally, Section 7 concludes the paper, followed by the appendices.

2 LITERATURE REVIEW

Several authors have discussed the use of P/BV valuation multipliers for various purposes. For instance, Monroy-Perdomo et al. (2022) conducted research on the Colombian market, focusing on the formalization of a new methodology for predicting stock trends based on the industry P/BV ratio. They explored the relationship between the market and book value of a stock/company's equity, along with other financial ratios (such as ROA, ROE), to predict market value creation.

Drábek and Syrovátka (2022) also examined this area in the context of the Czech brewing industry. They estimated the valuation multiplier for the industry using the P/BV ratio and compared its direct application with its decomposition through selected financial ratios (P/EAT, ROA, and financial leverage). Additionally, their paper outlined the potential for applying this differentiation to facilitate comparisons across industries.

The relationship between P/BV (or Tobin's Q) and financial ratios was also explored by González et al. (2020) to assess the impact of risk management implementation in listed companies.

In the context of Kuwaiti publicly traded companies, Al-Hares et al. (2012) analyzed value drivers such as book value of equity, earnings, and dividends, and their influence on the firm's market value. Essentially, they combined similar indicators to examine their effects. Furthermore, Ball et al. (2020) provided evidence that market-to-book strategies are effective, particularly through the consideration of retained earnings.

Park and Lee (2003) conducted an analysis on the accuracy of different relative valuation models and found that the P/BV ratio has the highest predictive ability. However, these conclusions are based on Japanese capital market data from almost 20 years ago. A more recent perspective on the market-to-book approach is presented by Ho et al. (2022), although their research primarily focuses on financial companies. The effectiveness of the market-to-book ratio in predicting the market value of publicly traded stocks in different markets is further supported by Cakici et al. (2015), who specifically examine the Chinese capital market.

In this paper, we will also utilize the association of the P/BV valuation multiple (or market-to-book) with other financial ratios. However, our approach differs significantly from the previously mentioned authors. Our objective is to differentiate the industry P/BV multiple in order to determine the market value of privately held companies. The main distinction arises from the lack of market value data (P) and corresponding P/BV multiple data for privately held companies. As we highlighted in the Introduction, using multiples derived from publicly traded companies is generally inappropriate due to differences in size, resource accessibility, risk levels, diversification opportunities, and other factors. This discrepancy is often referred to as the private company discount, as multiples for publicly traded companies tend to be higher than those for privately held companies.

Several studies have provided evidence supporting the existence of the private company discount. Examples include research conducted by Koeplin et al. (2005), Paglia and Harjoto (2010), and Klein and Scheibel (2012). Another valuable source of data on the private company discount is FactSet Mergerstat (2021), which compiles transaction information from both privately held and publicly traded companies

worldwide, allowing for the calculation of the private company discount based on these transactions.

From the aforementioned information, it is apparent that multiples derived from publicly traded companies can be utilized in the valuation of privately held companies, provided that a private company discount is applied. However, determining the appropriate level of discount poses a challenge due to considerable variations in the results reported by the authors cited above (ranging from 5% to 70%). Furthermore, these studies indicate that the discount level may differ between the US, the euro area, and emerging markets. Thus, we recognize the necessity of applying the private company discount when utilizing multiples derived from publicly traded company data. However, considering the specific nature of our sample data (as described in the Methods and Data section below), we opt to calculate our own multiples for privately held companies rather than relying on the wide range of figures found in existing literature.

3 METHODS AND DATA

Our initial dataset comprises 50 privately held companies operating within the brewing industry in the Czech Republic. The selection of this industry was based on the methodological procedure used, which requires an individual valuation of each company. In this regard, the chosen industry represents an ideal sample. It encompasses a sufficiently large number of companies while remaining manageable in terms of the valuation workload for each entity. Furthermore, this industry provides access to a substantial volume of analytical data, industry forecasts, and accounting information for individual companies. This abundance of data contributes to upholding the high credibility and reliability of the valuations performed. These 50 companies collectively accounting for over 99% of that industry's total turnover. However, for the purpose of the methodological procedure outlined below, it is necessary to make certain adjustments to the underlying dataset.

When analyzing the data for individual companies, we observed significant differences between the majority of medium and small breweries (44 in total) and the top 6 breweries in the industry under investigation. These top breweries, which are mostly large holding companies in terms of revenue and market capitalization, are comparable in size to publicly traded companies. Consequently, their valuation characteristics align closely with those of publicly traded companies, as indicated by their valuation multiples. Since our focus is primarily on privately held companies, especially those with distinct characteristics that differ from publicly traded companies, the inclusion of these top 6 breweries in our data sample could introduce bias. Therefore, we have excluded them from our analysis.

Another adjustment to the data was made by excluding loss-making companies, for the following reasons:

1. The use of the discounted cash flow (DCF) method to estimate market value is inappropriate for loss-making companies due to potential non-compliance with the going concern principle.
2. Loss-making companies may report a positive price-to-earnings after taxation (P/EAT) ratio as a result of multiplying two negative values. However, positive values obtained through this method do not align with the context of our calculations.
3. Publicly available databases of multiples for publicly traded companies typically include only profitable companies. To ensure comparability with these databases and facilitate the generalization of our proposed methodological upgrade, which involves the application of available multiples for publicly traded companies in conjunction with the private company discount (PCD), it is necessary to apply the same reduction to our dataset.

After excluding the top 6 brewery companies and all loss-making companies, our data sample consists of 26 companies in 2019 and 23 companies in 2020. However, we will also work with datasets that include the loss-making companies and the top 6 companies to compare the impact of our proposals on individual subsets of data. This comparison will enable us to evaluate the level of refinement achieved through the application of differentiated estimations to loss-making companies or companies that are not publicly traded but closely resemble publicly traded ones in terms of size and profile.

Following the application of the aforementioned reductions to the initial dataset of brewing companies for the years 2019 and 2020, four distinct subsamples were derived. The description and size (n) of each subsample are presented in Tab. 1. Based on the subsample sizes, adjustments were made to the Eq. 4.1, 4.2, 5.1, 5.2, 6.1, 6.2, 7.1, 7.2, 8.1, and 8.2. The descriptions of the datasets (columns) are as follows:

- "SME sample (+)" refers to the set of profitable breweries obtained by excluding the top 6 largest breweries.
- "SME sample (all)" refers to the complete set of breweries obtained by excluding the top 6 largest ones.
- "Full sample (+)" refers to the set of all profitable breweries.
- "Full sample (all)" refers to the full dataset comprising all 50 breweries.

Tab. 1: Sample size (n) and shares of the industry turnover (STR)

	SME sample (+)	**SME sample (all)**	**Full sample (+)**	**Full sample (all)**
2019	$n = 26$	$n = 44$	$n = 32$	$n = 50$
2020	$n = 23$	$n = 44$	$n = 29$	$n = 50$
STR	13.65%	15.20%	98.26%	99.65%

Note: STR represents the share of final dataset's turnover to the total turnover of the industry. Values are given as an average of both years.

Earnings (EAT), return on assets (ROA) and financial leverage (FL) data for the breweries in our sample were collected for the years 2019 and 2020 (more recent year data were not available at this time for the complete dataset of brewing companies). Since these are privately held companies, their market value of equity (P) was preliminary assessed using the discounted cash flow (DCF) method, as described in detail by Drábek (2022). These financial data are also available in the Annex (see Tab. 8).

The valuation of these privately held companies through the two-stage DCF method, focusing on the enterprise value (EV) level, employs the "entity" variant, which is represented as follows (see Damodaran, 2012):

$$\mathrm{EV} = \sum_{t=1}^{T} \frac{\mathrm{FCFF}_t}{(1+\mathrm{WACC})^t} + \frac{\mathrm{TV}}{(1+\mathrm{WACC})^T} \quad (1)$$

The variable FCFF represents the free cash flow to the firm, while TV represents the terminal value. WACC stands for the weighted average cost of capital, T represents the length of the first phase, and t represents the sequential number of years from the valuation date. The first phase of the model was set to last for 10 years, following the risk-free rate calculation method by Wenger (2003).

To compute the free cash flow to the firm, we begin with the after-tax operating profit and then deduct the net investment into invested operating capital, which includes both fixed assets and working capital components.

For the discount rate at the WACC level, we adopt Damodaran's (2012) cost of equity (re) calculation method according to Equation 2. To calculate the cost of debt, we consider either the actual negotiated rates for bank loans applicable to individual companies or refer to market data from the Czech National Bank (2021).

$$r_e = r_f + \beta \cdot (r_m - r_f) + r_c + r_{mc} \quad (2)$$

The variable r_f represents the risk-free interest rate, β reflects the coefficient indicating systematic risk, r_m denotes the expected market return, r_c stands for the country risk premium, and r_{mc} signifies the small market capitalisation premium.

To calculate the terminal value (TV), we apply a parametric formula based on the approach by Copeland et al. (1994), with modifications following Damodaran's (2012) methodology, as

shown below:

$$\mathrm{TV} = \frac{\mathrm{EBIT}_{T+1} \cdot (1 - \mathrm{RR})}{\mathrm{WACC} - g} \tag{3}$$

The variable EBIT_{T+1} denotes EBIT in the first year of the second phase, RR stands for the reinvestment rate in the second phase and g denotes the assumed free cash flow growth rate for the second phase.

After assessing the enterprise value, adjustments were made to account for non-operating items, and interest-bearing liabilities were subtracted, resulting in the determination of the market value of equity.

Next, the market value of equity for each brewery in the sample was transformed into a relative representation using multipliers, with reference to either the book value of equity (BV) or the net profit (EAT).

The entire valuation process adheres to the detailed description outlined by Drábek (2022). Based on the collected financial data, we first computed the industry P/BV multiplier in two forms. We distinguished the aggregate industry level (Eq. 4.1) and industry median (4.2). The calculations 4.1 and 4.2 were performed to obtain a comprehensive understanding of the industry's valuation characteristics.

$$\mathbb{A}\left[\frac{\mathrm{P}^*}{\mathrm{BV}}\right] = \frac{\sum \mathrm{P}_i^*}{\sum \mathrm{BV}_i} \tag{4.1}$$

$$\mathbb{M}\left[\frac{\mathrm{P}^*}{\mathrm{BV}}\right] = \mathrm{med}\left[\frac{\mathrm{P}^*}{\mathrm{BV}}\right]_i \tag{4.2}$$

The symbol $\mathbb{A}$ in the Eq. 4.1 represents the aggregated industry expression of P/BV, while the symbol $\mathbb{M}$ represents the calculation of P/BV based on the industry median. P^* represents the market value of equity assessed using the DCF method, BV represents the book value of equity, and i represents the serial number of a company ranging from 1 of n (size of the samples according to Tab. 1).

Similarly, the industry P/EAT multiplier was computed using a similar approach, both at the aggregate level (Eq. 5.1) and as a median (5.2).

$$\mathbb{A}\left[\frac{\mathrm{P}^*}{\mathrm{EAT}}\right] = \frac{\sum \mathrm{P}_i^*}{\sum \mathrm{EAT}_i} \tag{5.1}$$

$$\mathbb{M}\left[\frac{\mathrm{P}^*}{\mathrm{EAT}}\right] = \mathrm{med}\left[\frac{\mathrm{P}^*}{\mathrm{EAT}}\right]_i \tag{5.2}$$

In Eq. 5.1 and 5.2, the variable EAT represents the net earnings after taxation.

The Eq. 4.1, 4.2, 5.1 and 5.2 are the standard estimates of industry multipliers commonly used for valuation purposes. In the context of this paper, these equations serve as the baseline undifferentiated industry multipliers, which will be subsequently compared to the proposed upgraded methodology using differentiated industry multiplier estimates.

In order to align the industry multiplier more closely with the economic reality of the evaluated brewing company, the initial industry multipliers (Eq. 4.1 and 4.2) underwent a transformation, resulting in the emergence of differentiated multipliers labelled as Eq. 6.1 and 6.2.

$$\begin{aligned}\mathrm{dif}\,\mathbb{A}\left[\frac{\mathrm{P}^*}{\mathrm{BV}}\right]_i &= \mathbb{A}\left[\frac{\mathrm{P}^*}{\mathrm{EAT}}\right] \cdot \mathrm{ROA}_i \cdot \mathrm{FL}_i \\ &= \mathbb{A}\left[\frac{\mathrm{P}^*}{\mathrm{EAT}}\right] \cdot \frac{\mathrm{EAT}_i}{\mathrm{A}_i} \cdot \frac{\mathrm{A}_i}{\mathrm{BV}_i}\end{aligned} \tag{6.1}$$

$$\begin{aligned}\mathrm{dif}\,\mathbb{M}\left[\frac{\mathrm{P}^*}{\mathrm{BV}}\right]_i &= \mathbb{M}\left[\frac{\mathrm{P}^*}{\mathrm{EAT}}\right] \cdot \mathrm{ROA}_i \cdot \mathrm{FL}_i \\ &= \mathbb{M}\left[\frac{\mathrm{P}^*}{\mathrm{EAT}}\right] \cdot \frac{\mathrm{EAT}_i}{\mathrm{A}_i} \cdot \frac{\mathrm{A}_i}{\mathrm{BV}_i}\end{aligned} \tag{6.2}$$

The notation "dif" is used to describe the differentiated expression of the aggregate average level of the given multiplier (Eq. 6.1) and the differentiated expression of the median value of the multiplier (6.2). The variable A in Eq. 6.1 and 6.2 represents total assets.

Through the utilization of these refined differentiated multipliers (Eq. 6.1 and 6.2), we establish a more suitable framework for valuating individual companies within a given industry, as exemplified in our case study of breweries.

To assess the effectiveness of the differentiation approach, we compare the differentiated multipliers (Eq. 6.1 and 6.2) with the undifferentiated multipliers (Eq. 4.1 and 4.2) both in relation to the actual P/BV multiplier of each brewery (for both years 2019 and 2020). This allows us to measure the extent of deviation between the differentiated and undifferentiated

estimations. We use the absolute value of the relative deviation (ARD) as the evaluation metric for both the industry median and the aggregated industry multiplier. The ARDs for the differentiated multipliers are calculated according to Eq. 7.1 and 7.2 as follows:

$$\mathrm{ARD}_i^{\mathrm{dif}\,\mathbb{A}} = \left| \frac{\left[\frac{\mathrm{P}^*}{\mathrm{BV}}\right]_i - \mathrm{dif}\,\mathbb{A}\left[\frac{\mathrm{P}^*}{\mathrm{BV}}\right]_i}{\mathrm{dif}\,\mathbb{A}\left[\frac{\mathrm{P}^*}{\mathrm{BV}}\right]_i} \right| \tag{7.1}$$

$$= \left| \frac{\left[\frac{\mathrm{P}^*}{\mathrm{BV}}\right]_i}{\mathrm{dif}\,\mathbb{A}\left[\frac{\mathrm{P}^*}{\mathrm{BV}}\right]_i} - 1 \right|$$

$$\mathrm{ARD}_i^{\mathrm{dif}\,\mathbb{M}} = \left| \frac{\left[\frac{\mathrm{P}^*}{\mathrm{BV}}\right]_i - \mathrm{dif}\,\mathbb{M}\left[\frac{\mathrm{P}^*}{\mathrm{BV}}\right]_i}{\mathrm{dif}\,\mathbb{M}\left[\frac{\mathrm{P}^*}{\mathrm{BV}}\right]_i} \right| \tag{7.2}$$

$$= \left| \frac{\left[\frac{\mathrm{P}^*}{\mathrm{BV}}\right]_i}{\mathrm{dif}\,\mathbb{M}\left[\frac{\mathrm{P}^*}{\mathrm{BV}}\right]_i} - 1 \right|$$

The ARDs for undifferentiated industry multipliers are calculated using Eq. 7.3 and 7.4:

$$\mathrm{ARD}_i^{\mathbb{A}} = \left| \frac{\left[\frac{\mathrm{P}^*}{\mathrm{BV}}\right]_i - \mathbb{A}\left[\frac{\mathrm{P}^*}{\mathrm{BV}}\right]}{\mathbb{A}\left[\frac{\mathrm{P}^*}{\mathrm{BV}}\right]} \right| \tag{7.3}$$

$$= \left| \frac{\left[\frac{\mathrm{P}^*}{\mathrm{BV}}\right]_i}{\mathbb{A}\left[\frac{\mathrm{P}^*}{\mathrm{BV}}\right]} - 1 \right|$$

$$\mathrm{ARD}_i^{\mathbb{M}} = \left| \frac{\left[\frac{\mathrm{P}^*}{\mathrm{BV}}\right]_i - \mathbb{M}\left[\frac{\mathrm{P}^*}{\mathrm{BV}}\right]}{\mathbb{M}\left[\frac{\mathrm{P}^*}{\mathrm{BV}}\right]} \right| \tag{7.4}$$

$$= \left| \frac{\left[\frac{\mathrm{P}^*}{\mathrm{BV}}\right]_i}{\mathbb{M}\left[\frac{\mathrm{P}^*}{\mathrm{BV}}\right]} - 1 \right|$$

The achieved ARD deviations from Eq. 7.1, 7.2, 7.3 and 7.4 will be summarized separately for each relationship using the simple arithmetic mean and the total sum. The resulting "accuracy rate" (Δ) for estimating the market value of a company using a differentiated multiplier instead of an undifferentiated one will be calculated according to the following Eq. 8.1 and 8.2. Specifically, the calculation will be performed at both the aggregate level (Eq. 8.1) and the median level (8.2). Since the accuracy rate calculation should yield the same outcome mathematically using either the average ARD or the sum of ARD, we present the following equations using only the total sum of ARD:

$$\Delta_{\mathbb{A}} = \left[1 - \frac{\sum_i^n \mathrm{ARD}_i^{\mathrm{dif}\,\mathbb{A}}}{\sum_i^n \mathrm{ARD}_i^{\mathbb{A}}}\right] \tag{8.1}$$

$$\Delta_{\mathbb{M}} = \left[1 - \frac{\sum_i^n \mathrm{ARD}_i^{\mathrm{dif}\,\mathbb{M}}}{\sum_i^n \mathrm{ARD}_i^{\mathbb{M}}}\right] \tag{8.2}$$

The methodological approach described above assumes the availability of an industry P/BV or P/EAT ratio that is adjusted for the valuation of privately held companies, specifically in our case for the breweries under consideration. Typically, such a multiplier can be obtained by adjusting the multiplier for publicly traded companies using the private company discount (PCD) – for more details, refer to the Literature Review section. However, in our particular dataset, the condition of using a relevant industry multiplier is satisfied, and therefore, the industry multiplier we employ – as represented by Eq. 4.1, 4.2, 5.1 and 5.2 – does not require further adjustment. The generalization of our proposed methodological upgrade for any privately held company, considering the application of PCD, will be further discussed in the Discussion and Conclusions section.

4 RESULTS

In this section, we introduce our proposal for differentiating the industry multiplier to enhance the estimation process of individual companies' market value. This also includes the testing of our proposed methodological upgrade. The effectiveness of the refined valuation methodology based on industry multiples was evaluated within the context of the Czech brewing industry.

We computed the P/BV and P/EAT ratios for all 50 breweries using the market value P* assessed through the DCF method. Additionally, we calculated the relevant financial ratios required for Eq. 6.1 and 6.2. A detailed breakdown of these data can be found in the Annex (see Tab. 8).

With these data, we proceeded to calculate the differentiated P/BV ratios based on the industry median and the aggregate P/EAT ratios for each brewery, as outlined in Eq. 6.1 and 6.2. Subsequently, using Eq. 7.1 and 7.2, we computed the ARDs between these differentiated multipliers and the actual P/BV ratios for individual companies. A comprehensive summary of the ARDs for each brewery is provided in the Annex (see Tab. 9, 10, 11 and 12). The results of this analysis are presented in Tab. 2 and 3.

The first set of rows represents the ARD calculations based on the aggregate P/EAT multiplier for the Czech brewing industry, as described in Eq. 7.1. The second set of rows represents the ARD calculations based on the median P/EAT multiplier, as outlined in Eq. 7.2.

Tab. 2 demonstrates that there has been a consistent year-on-year decrease in the overall ARD for individual companies. The calculations based on the reduced sample of 26 or 23 profitable breweries yielded the lowest ARD values. Interestingly, the inclusion of the largest 6 companies in the industry, even in the full sample of only profitable breweries, did not have a substantial impact on the results. Furthermore, calculations based on the aggregate P/EAT for the entire industry generally exhibited lower accuracy compared to those based on the industry median. Standard deviations are displayed in parentheses.

Tab. 2: Sum of ARD for each sample and P/EAT type in 2019 and 2020 – differentiated approach

Sum of ARD	SME sample (+)	SME sample (all)	Full sample (+)	Full sample (all)
Aggregate P/EAT				
2019	17.88	651.46	26.11	224.59
	(1.69)	(29.52)	(2.06)	(10.97)
2020	12.47	262.16	17.67	304.89
	(0.48)	(10.39)	(0.57)	(13.16)
Median P/EAT				
2019	18.22	134.04	20.95	146.25
	(1.73)	(6.83)	(1.68)	(7.02)
2020	10.39	116.73	15.01	164.11
	(0.40)	(4.84)	(0.47)	(6.83)

Note: Standard deviations are displayed in parentheses.

Turning to Tab. 3, which presents the differentiated estimates, it provides the average ARD for each sample and P/EAT type in 2019 and 2020. Notably, the reduced sample of profitable breweries in 2020 displayed significantly lower average ARD values. However, it can be observed that there was no significant difference between the reduced sample and the full sample when considering only profitable companies in both cases.

Tab. 3: Average ARD for each sample and P/EAT type in 2019 and 2020 – differentiated approach

Average ARD	SME sample (+)	SME sample (all)	Full sample (+)	Full sample (all)
Aggregate P/EAT				
2019	0.69	14.81	0.82	4.49
	(1.69)	(29.52)	(2.06)	(10.97)
2020	0.54	5.96	0.61	6.10
	(0.48)	(10.39)	(0.57)	(13.16)
Median P/EAT				
2019	0.70	3.05	0.65	2.92
	(1.73)	(6.83)	(1.68)	(7.02)
2020	0.45	2.65	0.52	3.28
	(0.40)	(4.84)	(0.47)	(6.83)

Note: Standard deviations are displayed in parentheses.

The subsequent tables, namely Tab. 4 and Tab. 5, present the calculation of ARD using the

undifferentiated estimates of each company's multipliers based on Eq. 7.3 and 7.4, along with their corresponding actual P/BV ratios. A comprehensive summary of the ARDs for individual breweries can be found in the Annex (see Tab. 9 to 12).

Tab. 4: Sum of ARD for each sample and P/BV type in 2019 and 2020 – undifferentiated approach

Sum of ARD	**SME sample (+)**	**SME sample (all)**	**Full sample (+)**	**Full sample (all)**
Aggregate P/BV				
2019	24.76 (1.45)	45.04 (1.07)	106.01 (5.36)	233.67 (5.70)
2020	16.01 (1.00)	45.49 (1.44)	79.14 (3.80)	285.74 (7.79)
Median P/BV				
2019	32.70 (2.22)	42.99 (0.99)	40.78 (2.27)	52.65 (1.14)
2020	20.90 (1.48)	49.10 (1.61)	26.76 (1.44)	55.44 (1.61)

Note: Standard deviations are displayed in parentheses.

Tab. 4 illustrates that even with undifferentiated estimates, the calculations based on a reduced sample of 26, respectively 23, profitable breweries yield the best results with the lowest sum of ARD. However, the differences between the calculations are not as significant as observed in the case of differenced estimates, as indicated in Tab. 2 and Tab. 3. Standard deviations are displayed in parentheses.

Tab. 5: Average ARD for each sample and P/BV type in 2019 and 2020 – undifferentiated approach

Average ARD	**SME sample (+)**	**SME sample (all)**	**Full sample (+)**	**Full sample (all)**
Aggregate P/BV				
2019	0.95 (1.45)	1.02 (1.07)	3.31 (5.36)	4.67 (5.70)
2020	0.70 (1.00)	1.03 (1.44)	2.73 (3.80)	5.71 (7.79)
Median P/BV				
2019	1.26 (2.22)	0.98 (0.99)	1.27 (2.27)	1.05 (1.14)
2020	0.91 (1.48)	1.12 (1.61)	0.92 (1.44)	1.11 (1.61)

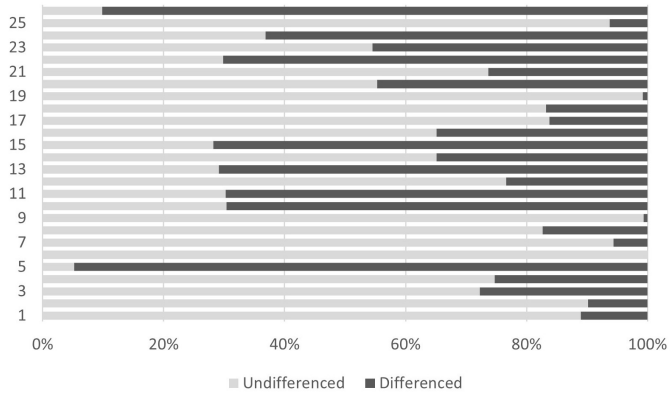
Note: Standard deviations are displayed in parentheses

Tab. 5, which pertains to undifferentiated estimates, presents the average ARD for each sample and P/BV type in 2019 and 2020. According to Tab. 5, the average ARD indicates minimal differences among the data samples in the computation of undifferenced estimates. Nonetheless, the majority of the lowest values in the first column, corresponding to the calculation based on a reduced sample of profitable companies, are notable.

Based on the information presented in Tab. 2–5, it appears that differential valuation does not consistently provide more accurate estimates of companies' market value in all cases. However, it is important to note that our research primarily focuses on a reduced sample of profitable companies – SME sample (+), as mentioned earlier in this section, and the other columns serve as supplementary information. Overall, it is evident that the ARD is higher when using datasets that include loss-making companies compared to datasets consisting only of profitable companies. This implies that in the case of loss-making companies, the use of differenced estimation would result in increased inaccuracy. It should be emphasized that our proposed approach does not consider the application of differenced estimation to loss-making companies, as the relative valuation approach typically assumes the going concern principle.

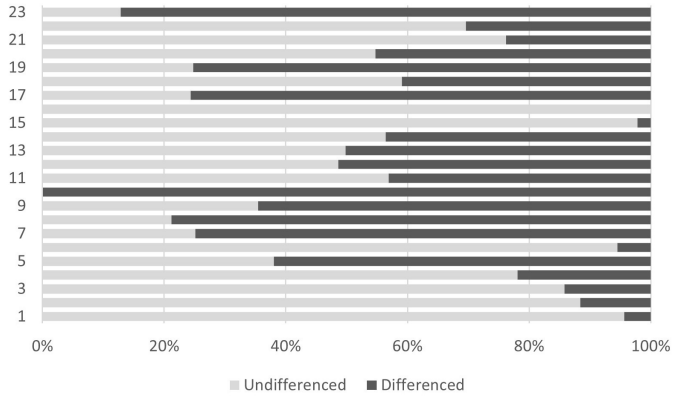
Fig. 1 and Fig. 2 provide a comparison of the ARD for each brewery (represented on the y-axis) between differenced and undifferenced estimates. The stacked graphs, presented as percentages, are used for the comparison. Fig. 1 illustrates the results at the median level of the applied industry multiplier for 2019, while Fig. 2 depicts analogous results for 2020. A comparison of ARDs at the aggregate level of the industry multiplier can be found in the Annex (see Fig. 3).

Fig. 1 illustrates that the ARD is significantly higher when undifferenced estimation is used for the majority of breweries. Interestingly, the application of differenced estimation yields an almost perfect match with the actual P/BV multiplier. Fig. 2 shows that for most breweries the ARD is higher when undifferenced estimation is employed. In two cases, the use of



Note: The y-axis represents the serial number of each brewery "i" within the data sample. The dark bars in the graph represent the ARDs for the differenced estimates, while the light bars represent the undifferenced estimates. The data presented in the graph are based on the median level of the applied industry multiplier for 2019.

Fig. 1: A comparison of the ARD of each brewery in 2019 for the differenced and undifferenced estimates



The y-axis represents the serial number of each brewery "i" within the data sample. Dark bars indicate the ARDs for differenced estimates, while light bars represent undifferenced estimates. The data presented in the figure correspond to the median level of the applied industry multiplier for 2020.

Fig. 2: A comparison of the ARD of each brewery in 2020 for the differenced and undifferenced estimates

differenced estimation even leads to an almost perfect match with the actual P/BV multiplier. Conversely, in one instance, the adoption of differenced estimation results in an increase in the inaccuracy of an initially precise estimate.

The final comparison and evaluation of the aforementioned calculations, along with the extent of improvement in market value estimation using our proposed differentiated multipliers, are displayed in Tab. 6. The ultimate assessment is conducted based on Eq. 8.1 and 8.2. We solely present the outcomes for profitable breweries, considering two reduced samples (with and without the top 6 largest breweries), as the application of these results is meaningful only if the going concern principle is upheld.

Tab. 6: The degree of refinement of the market value estimates of individual companies using differentiated industry multipliers

	SME sample (+)	**Full sample (+)**
Aggregated level:		
2019	27.77%	75.37%
2020	22.15%	77.68%
Median level:		
2019	44.28%	48.62%
2020	50.29%	43.92%

Tab. 6 presents the refinement of market value estimates for individual breweries using differentiated industry multipliers, based on the median values. The results indicate a refinement ranging from approximately 44% to 50% for both studied years. This refinement is almost comparable between the full and reduced samples of profitable SME companies. On an aggregate basis of industry multiplier, the refinement rate is 27.77% in 2019 and 22.15% in 2020 for the reduced sample of profitable SME companies. However, when the top 6 companies are included, the refinement rate increases significantly to 75–78%.

5 ROBUSTNESS ANALYSIS

In this section, we examine the robustness of the results by applying our proposed differentiation to the valuation multiples of publicly traded European companies in several other industries. The results of this analysis are presented in Tab. 7.

Tab. 7 demonstrates that implementing our industry multiplier differentiation on publicly traded company data leads also to a more precise estimation of market value when using the industry multiplier method. In contrast to the findings from the analysis of 50 unlisted Czech breweries, we do not segregate the sample into companies with positive and negative market values in this case, as all publicly traded companies included in the robustness analysis exhibit positive market values. Additionally, the classification into small, medium-sized, and similar publicly traded ones is irrelevant for this analysis.

The results in Tab. 7 indicate that the application of our proposed differentiation method to the given samples of publicly traded companies achieves some level of refinement in both years included. The results exhibit significant variation, both across different industries and over different years. However, it's important to note that the primary aim here is not to derive exact industry-specific values or to draw specific conclusions about relative differences between these industries. Instead, our objective is to validate the general applicability of the proposed methodology, a goal that has been successfully achieved based on the presented data.

It's important to acknowledge that all our results are derived solely from reported values of the reference variables, which may inherently contain various biases. However, in practical applications, it's common to apply normalization or adjustments to these reference variables. In our perspective, such normalization or adjustments should further enhance the connection between the differenced multiplier and the financial variables used. This enhancement is expected to result in even greater levels of refinement. Nevertheless, implementing these adjustments could potentially compromise the objectivity of the research, and it would also entail a substantial amount of time and effort, given that it would need to be executed for both the 50 Czech breweries and the hundreds publicly traded companies involved in the robustness analysis.

Tab. 7: The degree of refinement using differentiated industry multipliers for publicly traded companies (Damodaran, 2020 and 2021)

	Auto & Truck	**Beverage (alcoholic)**	**Building Materials**	**Electrical Equipment**	**Retail (distributors)**	**Utility (water)**
2019	69.95%	43.26%	11.04%	12.19%	30.11%	32.10%
2020	50.26%	63.93%	31.90%	35.65%	14.21%	85.02%

Note: Calculations performed at the median level, excluding values of P/E ratio < 1 and > 500.

6 DISCUSSION

Based on our findings, it is evident that the proposed methodological upgrade significantly enhances the accuracy of equity market value estimates. However, we must acknowledge that our results are not entirely generalizable, as the differentiation method does not lead to increased accuracy for loss-making firms or those with negative equity. It is important to emphasize that companies failing to meet the going concern principle should be valued using the liquidation method rather than the DCF method or the industry multiple approach. Consequently, considering these non-going concern companies when attempting to improve the methodology would be futile. Conversely, our results can be applied universally to any industry, regardless of size or stock market exposure.

This approach offers a distinct advantage as it involves objective adjustments of the original industry multiplier based on the financial ratios of each individual company (refer to Eq. 6.1 and 6.2). These financial ratios are derived solely from the accounting data of each company, allowing for the application of this procedure to all privately held companies lacking market value data. However, it is crucial to have an initial industry multiplier, which can be obtained from fee-based or freely available databases predominantly comprising data from publicly traded companies.

As mentioned in earlier sections, directly applying an industry valuation multiplier derived from publicly traded company data is generally inappropriate for privately held companies, particularly those that are small or medium-sized. In such cases, it is recommended to incorporate a private company discount during the valuation process. As discussed in the Literature Review section, the magnitude of this discount varies between 5% and 70% based on different studies. For our sample of profitable breweries, excluding the six largest ones, the private company discount values are determined as 55.62% in 2019 and 59.94% in 2020, employing the Drábek and Pastorek (2023) methodology. These values align with the aggregated industry P/BV ratio. Detailed information on the inputs used to calculate the private company discount can be found in the Annex (see Tab. 13) of this paper.

Our proposed differentiation of the industry valuation multiplier is inherently effective even without the aforementioned modification. However, to achieve the highest accuracy and applicability for privately held companies, we suggest an additional step. In the case of using the multiplier calculated from publicly traded company values in Eq. 5.1 and 5.2, we propose reducing this industry multiplier by the private company discount (PCD) and subsequently applying our differentiated approach according to Eq. 6.1 and 6.2.

It is important to note that the private company discount values mentioned earlier are specific to the Czech brewing industry. The discount amount may vary across different industries or countries. Therefore, we recommend validating the calculated private company discount values before applying them to other industries. This can be done by estimating the market value of random companies in a given industry using alternative methods like the discounted cash flow (DCF) approach or by considering actual transactions involving companies. However, exploring the applicability of these values to other markets and industries falls beyond the scope of this paper.

It should be acknowledged that private company discount values are typically reported broadly across industries, often with a geographic focus, if any. This implies that the private company discount may not vary significantly across industries, which theoretically contradicts the essence of the discount as it arises from the disparities between publicly traded and privately held companies.

To summarize, it is important to emphasize that the considerations regarding private company discount do not impact the conclusions of this paper regarding the methodological improvement achieved through differential estimations.

Regrettably, we could not find any relevant studies that directly addressed the refinement of the industry multiplier methodology, making direct comparisons challenging. The differentiation of the industry P/BV multiplier as mentioned in Drábek and Syrovátka (2022) was solely used by those authors as an alternative means of determining the P/BV multiplier and for cross-sectoral comparisons. Its applicability to privately held companies using private company discount was not a focus of their research. Our study, on the other hand, use that financial decomposition to differentiate the industry multiplier for the purpose of refining the estimation of the market value of any firm (with an emphasis on unlisted ones) and work in addition with a doubly large dataset enabling dynamic insights.

The literature review revealed that other studies mainly focus on the P/BV ratio in general and do not offer relevant comparisons with our specific findings. Therefore, our research represents a unique contribution in the field. When comparing our proposed methodological approach with the conventional valuation methodology that employs multipliers at the level of a specific mean value (as discussed by Mařík et al., 2018; Damodaran 2012; Dittmann and Maug, 2008; and others), our contribution, in terms of enhanced estimation accuracy, aligns with the results presented in Tab. 6.

As we mentioned in the introduction to the Discussion, our proposed methodological upgrade is not suitable for application in the case of loss-making companies. This is because the relative valuation approach requires compliance with the going concern principle. Furthermore, since the primary multipliers (P/BV and P/E) are derived from publicly traded companies' data and thus achieve positive values, their application to companies with negative reference variables is not possible. Mathematically, it would always lead to a negative value. However, this may not be the correct approach, as, for example, start-ups, even in their initial phase of incurring losses, often have a certain (positive) market value. This fact is a limitation of our research. It must be added, though, that our proposal could find application in the valuation of start-ups within the DCF method. One variant of valuing start-ups is the combination of the standard DCF method with a perpetuity phase determined by a valuation multiplier, known as the venture capital method (see e.g. Puca, 2020). In this method, after a stabilization period, for which a financial plan is created and cash flow is generated (usually partially negative), the stabilized reference variable (positive) is multiplied by the industry multiplier, determining the value of the second phase. Typically, in these cases, the value of the second phase constitutes a large majority of the total market value. To determine the value within this second phase, the application of our proposed methodological improvement, which could enhance the accuracy of market value estimation, is considered. This could be especially relevant for start-ups. However, this is a consideration that we do not have evidence to support and would require additional research.

7 CONCLUSIONS

The objective of this paper was to develop and apply a methodological procedure for valuing privately held companies, specifically within the Czech brewing industry. This was achieved by differentiating estimates of the industry P/BV multiplier through the decomposition of the P/BV multiplier into P/EAT, ROA, and FL.

Based on the findings presented in the Results section, we can conclude that the application of a differentiated industry multiplier leads to significantly more accurate estimations of the market value of an equity compared to using the median or aggregate value for a given industry.

Our proposed methodological approach can be applied generally to any sample of companies meeting the going concern, achieving a positive market value of equity respectively, regardless of size and stock market location. This has been supported by the robustness analysis (Section 5).

By applying our proposed differentiation, the valuation method of industry multipliers becomes significantly more accurate in estimating the market value of a company; not only publicly traded companies but especially unlisted ones. This improvement is further enabled by incorporating the application of a private company discount (PCD), which allows for a broader and more general application of the methodology by incorporating multiples derived from publicly traded company data into the valuation of privately held companies.

In conclusion, our research demonstrates that implementing a differentiated approach to assess a company's market value using industry multipliers significantly enhances the accuracy of the estimate. The improvement ranges from 40% to 50% when using the median industry multiplier and approximately 22% to 78% when using the aggregate industry multiplier. We believe this contribution is of great significance to all involved in the methodological and practical aspects of business valuation.

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10 ANNEX

Tab. 8: Financial data of the companies in the sample (th. EUR, ROA and FL dimensionless)

No.	P* 2019	P* 2020	EAT 2019	EAT 2020	ROA 2019	ROA 2020	FL 2019	FL 2020
1.	4,171,922	3,707,163	187,682	145,780	0.32	0.26	2.18	5.79
2.	666,393	607,198	25,659	30,749	0.03	0.03	1.12	1.11
3.	291,301	256,714	13,226	4,393	0.12	0.05	2.83	3.25
4.	311,130	317,988	10,943	11,621	0.05	0.05	1.14	1.14
5.	150,088	139,732	5,811	3,520	0.12	0.06	3.15	3.08
6.	168,111	151,335	6,467	3,777	0.13	0.07	1.35	1.31
7.	7,543	9,494	−118	537	0.00	0.02	1.76	1.52
8.	10,675	12,254	734	777	0.03	0.04	1.20	1.13
9.	4,448	7,044	309	311	0.02	0.02	1.67	1.51
10.	6,747	4,560	−428	−415	−0.04	−0.04	1.89	1.69
11.	9,184	11,168	280	728	0.02	0.05	1.15	1.16
12.	3,369	3,340	208	243	0.05	0.06	2.65	2.44
13.	8,623	7,482	623	395	0.08	0.05	1.41	1.38
14.	21,595	20,087	1,208	346	0.10	0.03	1.18	1.15
15.	15,725	13,318	888	546	0.09	0.05	1.27	1.26
16.	3,240	2,506	143	−367	0.03	−0.08	1.32	1.37
17.	−1,664	−2,531	−1,283	−766	−0.14	−0.09	4.94	8.08
18.	−76	641	−199	−47	−0.09	−0.02	5.62	5.44
19.	3,439	2,516	−83	−550	−0.01	−0.08	1.28	1.28
20.	−21,011	−22,478	−2,840	−2,585	−0.16	−0.15	1.45	1.78
21.	−1,186	−2,482	−1,561	−1,159	−0.19	−0.14	3.94	1.80
22.	2,071	1,125	113	−1,886	0.01	−0.19	2.01	2.41
23.	2,591	350	150	−62	0.03	−0.01	3.04	3.07
24.	3,472	3,211	257	42	0.06	0.01	1.86	1.64
25.	1,946	1,217	18	−44	0.00	−0.01	1.21	1.16
26.	3,397	2,797	104	114	0.02	0.03	2.77	2.49
27.	2,186	2,201	−73	−70	−0.01	−0.01	1.24	1.21
28.	1,638	1,462	37	4	0.01	0.00	1.20	1.24
29.	−433	−174	−160	−248	−0.06	−0.10	27.71	−16.24
30.	1,175	1,042	−988	−956	−0.14	−0.20	1.77	1.21
31.	1,015	595	1	−89	0.00	−0.08	1.48	1.53
32.	2,887	2,675	123	85	0.04	0.02	3.30	3.29
33.	934	272	54	36	0.04	0.03	2.51	2.89
34.	4,359	4,079	220	146	0.08	0.05	2.04	1.83
35.	382	223	−580	−562	−0.20	−0.25	3.41	2.66
36.	1,463	721	80	−169	0.02	−0.05	1.25	1.16
37.	244	321	137	20	0.06	0.01	1.24	1.19
38.	2,502	1,955	−1	−33	0.00	−0.01	1.40	1.34
39.	4,660	4,898	309	261	0.20	0.15	1.08	1.07
40.	1,349	1,261	−91	−105	−0.03	−0.03	1.05	1.04
41.	1,201	887	16	37	0.03	0.05	1.24	1.56
42.	−1,683	−1,660	−156	−151	−0.26	−0.26	15.53	15.53
43.	422	957	−3	93	0.00	0.06	1.15	1.14
44.	498	56	69	67	0.12	0.12	−0.92	−0.92
45.	1,352	947	71	0	0.06	0.00	1.36	1.54
46.	3,768	3,979	313	260	0.19	0.14	0.99	1.01
47.	450	1,367	29	93	0.08	0.20	−20.31	6.33
48.	1,756	1,452	92	101	0.10	0.10	10.30	4.00
49.	524	588	101	71	0.23	0.14	1.88	1.65
50.	−175	−131	−44	−42	−0.05	−0.05	1.12	1.10

Tab. 9: Summary of the ARDs for individual breweries using differentiated and undifferentiated multipliers for full sample (all)

No.	Differentiated				Undifferentiated			
	Median 2019	Median 2020	Aggregated 2019	Aggregated 2020	Median 2019	Median 2020	Aggregated 2019	Aggregated 2020
1.	0.31	0.45	0.07	0.07	0.95	0.98	0.76	0.90
2.	0.41	0.29	0.09	0.37	0.00	0.09	3.76	4.31
3.	0.31	0.76	0.08	0.54	0.89	0.91	0.49	0.56
4.	0.46	0.49	0.17	0.01	0.52	0.52	1.30	1.34
5.	0.41	0.65	0.08	0.32	0.92	0.89	0.60	0.49
6.	0.41	0.65	0.09	0.32	0.82	0.79	0.14	0.04
7.	1.24	0.21	1.37	0.53	0.49	0.19	6.10	4.79
8.	0.05	0.11	0.63	0.72	0.42	0.24	5.74	5.03
9.	0.06	0.38	0.65	0.20	0.60	0.02	6.63	3.95
10.	1.97	2.28	2.50	3.47	0.32	0.04	2.23	3.69
11.	0.53	0.08	0.28	0.77	0.09	0.09	4.16	3.41
12.	0.06	0.02	0.46	0.97	0.66	0.61	0.63	0.89
13.	0.10	0.26	0.71	0.43	0.51	0.43	1.32	1.78
14.	0.14	0.76	0.33	0.53	0.63	0.61	0.77	0.89
15.	0.14	0.42	0.34	0.11	0.58	0.53	0.99	1.29
16.	0.33	3.06	0.04	4.98	0.00	0.11	3.76	4.43
17.	10.78	3.26	17.27	7.21	1.89	1.32	5.23	2.56
18.	38.99	2.03	61.00	2.98	5.26	0.58	21.28	1.07
19.	1.37	4.07	1.57	6.93	0.37	0.62	5.52	6.87
20.	1.07	0.62	2.20	2.12	1.48	1.34	3.27	2.64
21.	19.12	5.56	30.19	11.67	2.42	2.44	7.76	8.00
22.	0.17	24.57	0.29	46.49	1.58	1.87	11.27	12.97
23.	0.11	3.50	0.38	5.83	0.50	2.68	1.40	16.94
24.	0.13	0.82	0.76	0.64	0.43	0.29	1.70	2.45
25.	0.86	1.50	0.79	1.97	0.86	1.82	7.86	12.75
26.	0.53	0.43	0.28	0.10	0.60	0.50	0.92	1.44
27.	1.51	1.45	1.79	1.87	1.41	1.29	10.46	10.16
28.	0.66	0.96	0.47	0.93	0.05	0.13	4.00	4.50
29.	4.65	19.07	7.75	37.73	1.18	0.30	1.85	2.41
30.	13.85	13.90	20.92	25.90	1.79	2.01	12.27	13.66
31.	0.99	3.11	0.98	5.07	0.31	0.01	2.27	3.90
32.	0.35	0.55	0.01	0.14	0.72	0.69	0.31	0.51
33.	0.12	0.86	0.37	2.58	0.59	0.24	0.97	5.04
34.	0.23	0.50	0.20	0.03	0.74	0.71	0.22	0.41
35.	24.19	36.33	36.96	69.20	0.82	1.98	7.65	13.51
36.	0.16	4.30	0.30	7.37	0.62	1.96	6.70	13.42
37.	7.56	0.13	12.27	0.68	5.03	3.24	27.70	19.68
38.	1.01	1.24	1.01	1.46	0.18	0.01	2.92	3.85
39.	0.01	0.25	0.57	0.44	0.76	0.74	0.14	0.27
40.	2.03	2.17	2.60	3.25	0.83	0.81	7.70	7.80
41.	0.80	0.41	0.69	0.14	0.67	0.53	0.59	1.28
42.	0.42	0.28	1.20	1.47	1.02	1.02	1.09	1.09
43.	1.09	0.37	1.15	1.64	1.43	0.10	10.57	4.37
44.	1.11	15.65	2.27	31.14	2.03	9.75	5.91	43.66
45.	0.20	1.00	0.25	1.00	0.47	0.33	1.53	2.24
46.	0.27	0.08	0.97	0.77	0.64	0.64	0.69	0.77
47.	0.01	0.04	0.53	0.85	1.03	0.96	1.16	0.79
48.	0.20	0.02	0.24	0.89	0.96	0.86	0.80	0.30
49.	1.96	0.71	3.58	2.29	0.64	0.59	0.73	0.98
50.	2.81	3.54	4.91	7.76	4.96	6.06	19.82	25.66

Tab. 10: Summary of the ARDs for individual breweries using differentiated and undifferentiated multipliers for full sample (+)

No.	Differentiated				Undifferentiated			
	Median 2019	Median 2020	Aggregated 2019	Aggregated 2020	Median 2019	Median 2020	Aggregated 2019	Aggregated 2020
1.	0.14	0.11	0.03	0.02	0.89	0.96	0.75	0.90
2.	0.27	0.15	0.12	0.31	1.23	1.32	3.95	4.56
3.	0.14	0.61	0.04	0.56	0.76	0.81	0.47	0.54
4.	0.33	0.17	0.19	0.06	0.08	0.02	1.40	1.45
5.	0.26	0.43	0.11	0.35	0.81	0.78	0.59	0.46
6.	0.27	0.44	0.12	0.36	0.60	0.54	0.11	0.09
7.		0.28		0.46		1.53		5.07
8.	0.31	0.43	0.57	0.64	2.16	1.63	6.02	5.31
9.	0.32	0.00	0.59	0.14	2.58	1.16	6.95	4.19
10.								
11.	0.42	0.48	0.30	0.68	1.42	0.92	4.38	3.62
12.	0.17	0.64	0.42	0.88	0.23	0.17	0.70	0.98
13.	0.37	0.19	0.65	0.36	0.09	0.21	1.42	1.91
14.	0.06	0.61	0.28	0.56	0.17	0.18	0.85	0.98
15.	0.07	0.07	0.29	0.06	0.07	0.00	1.07	1.40
16.	0.16		0.01		1.23		3.96	
17.								
18.								
19.								
20.								
21.								
22.	0.03		0.25		4.76		11.79	
23.	0.10		0.33		0.13		1.50	
24.	0.41	0.70	0.70	0.66	0.26	0.51	1.81	2.62
25.	0.83		0.79		3.16		8.23	
26.	0.42	0.08	0.30	0.05	0.10	0.07	1.00	1.56
27.								
28.	0.57	0.94	0.48	0.93	1.34	1.40	4.21	4.76
29.								
30.								
31.	0.98		0.98		0.54		2.41	
32.	0.19	0.28	0.02	0.18	0.38	0.34	0.37	0.58
33.	0.10	1.99	0.32	2.41	0.07	1.64	1.05	5.33
34.	0.04	0.19	0.16	0.07	0.43	0.38	0.27	0.48
35.								
36.	0.04		0.26		2.61		7.02	
37.	9.65	0.40	11.83	0.60	12.46	8.02	28.90	20.66
38.								
39.	0.26	0.20	0.52	0.37	0.46	0.45	0.19	0.33
40.								
41.	0.75	0.05	0.70	0.08	0.25	0.01	0.66	1.38
42.								
43.		1.20		1.51		1.34		4.62
44.								
45.	0.00	1.00	0.20	1.00	0.19	0.42	1.64	2.40
46.	0.58	0.48	0.90	0.69	0.21	0.23	0.76	0.85
47.		0.55		0.76		0.91		0.78
48.	0.00	0.58	0.20	0.80	0.91	0.69	0.79	0.26
49.	2.68	1.75	3.43	2.13	0.19	0.14	0.80	1.07
50.								

Tab. 11: Summary of the ARDs for individual breweries using differentiated and undifferentiated multipliers for SME sample (all)

No.	Differentiated				Undifferentiated			
	Median 2019	Median 2020	Aggregated 2019	Aggregated 2020	Median 2019	Median 2020	Aggregated 2019	Aggregated 2020
1.								
2.								
3.								
4.								
5.								
6.								
7.	1.22	0.46	0.05	2.19	0.23	0.12	0.33	0.00
8.	0.03	0.40	5.17	2.34	0.17	0.17	0.26	0.05
9.	0.02	0.58	5.22	1.93	0.32	0.04	0.43	0.14
10.	1.90	1.86	2.85	0.92	0.44	0.09	0.39	0.19
11.	0.57	0.38	2.85	2.38	0.10	0.14	0.03	0.23
12.	0.13	0.31	4.75	2.54	0.72	0.63	0.69	0.67
13.	0.02	0.50	5.38	2.12	0.60	0.46	0.56	0.52
14.	0.21	0.84	4.39	1.36	0.69	0.63	0.67	0.67
15.	0.20	0.61	4.43	1.87	0.66	0.56	0.63	0.60
16.	0.38	2.39	3.67	2.10	0.17	0.05	0.11	0.06
17.	9.88	1.87	47.76	7.40	1.73	1.30	1.79	1.27
18.	35.92	1.69	159.69	0.54	4.52	0.60	4.81	0.64
19.	1.34	3.07	0.46	3.62	0.13	0.53	0.22	0.37
20.	0.91	0.09	9.20	3.43	1.39	1.32	1.43	1.28
21.	17.57	3.43	80.83	10.87	2.17	2.36	2.27	2.21
22.	0.23	16.90	4.30	34.45	1.13	1.71	1.30	1.42
23.	0.18	2.69	4.52	2.77	0.58	2.48	0.55	2.11
24.	0.05	0.88	5.50	1.28	0.53	0.33	0.49	0.40
25.	0.87	1.34	1.55	0.24	0.54	1.67	0.66	1.38
26.	0.57	0.61	2.85	1.86	0.67	0.53	0.64	0.58
27.	1.47	1.30	1.02	0.32	0.99	1.17	1.15	0.93
28.	0.68	0.97	2.37	1.06	0.13	0.07	0.06	0.05
29.	4.21	12.54	23.41	31.18	1.15	0.34	1.16	0.41
30.	12.86	9.71	49.99	18.41	1.30	1.85	1.49	1.54
31.	0.99	2.42	1.06	2.17	0.43	0.05	0.39	0.15
32.	0.40	0.70	3.59	1.67	0.77	0.71	0.75	0.74
33.	0.19	0.25	4.50	3.79	0.66	0.17	0.63	0.05
34.	0.29	0.66	4.06	1.76	0.79	0.73	0.77	0.76
35.	22.41	24.84	91.03	52.15	0.50	1.82	0.62	1.52
36.	0.22	3.23	4.33	3.96	0.34	1.80	0.45	1.50
37.	6.90	0.41	34.97	2.31	3.98	3.01	4.39	2.59
38.	1.00	1.16	0.98	0.64	0.32	0.06	0.26	0.16
39.	0.07	0.50	5.02	2.12	0.80	0.75	0.79	0.78
40.	1.95	1.79	3.10	0.76	0.51	0.71	0.63	0.53
41.	0.82	0.60	1.79	1.89	0.72	0.56	0.70	0.61
42.	0.31	0.14	6.64	2.93	1.02	1.02	1.02	1.01
43.	1.09	0.08	0.63	3.06	1.01	0.04	1.17	0.07
44.	0.95	10.24	9.38	26.05	1.85	9.28	1.92	8.40
45.	0.26	1.00	4.19	1.00	0.56	0.37	0.52	0.44
46.	0.17	0.38	6.04	2.38	0.71	0.66	0.68	0.69
47.	0.09	0.35	4.92	2.45	1.03	0.96	1.03	0.96
48.	0.26	0.34	4.19	2.47	0.97	0.86	0.96	0.88
49.	1.73	0.15	12.73	3.57	0.70	0.62	0.68	0.66
50.	2.52	2.06	16.13	7.83	4.26	5.79	4.53	5.28

Tab. 12: Summary of the ARDs for individual breweries using differentiated and undifferentiated multipliers for SME sample (+)

No.	Differentiated				Undifferentiated			
	Median 2019	Median 2020	Aggregated 2019	Aggregated 2020	Median 2019	Median 2020	Aggregated 2019	Aggregated 2020
1.								
2.								
3.								
4.								
5.								
6.								
7.		0.06		0.23		1.37		0.75
8.	0.23	0.19	0.20	0.38	1.85	1.47	1.04	0.82
9.	0.24	0.17	0.21	0.04	2.23	1.03	1.31	0.49
10.								
11.	0.45	0.23	0.47	0.42	1.19	0.81	0.56	0.33
12.	0.10	0.37	0.08	0.58	0.31	0.22	0.51	0.43
13.	0.29	0.01	0.26	0.15	0.02	0.14	0.30	0.16
14.	0.00	0.68	0.02	0.63	0.25	0.23	0.46	0.43
15.	0.01	0.23	0.01	0.11	0.16	0.06	0.40	0.31
16.	0.21		0.23		1.01		0.44	
17.								
18.								
19.								
20.								
21.								
22.	0.03		0.05		4.20		2.71	
23.	0.04		0.01		0.02		0.27	
24.	0.33	0.75	0.30	0.72	0.14	0.41	0.18	0.04
25.	0.84		0.84		2.75		1.68	
26.	0.45	0.24	0.47	0.12	0.19	0.00	0.42	0.26
27.								
28.	0.60	0.95	0.61	0.94	1.12	1.25	0.51	0.66
29.								
30.								
31.	0.98		0.98		0.39		0.01	
32.	0.24	0.40	0.26	0.31	0.44	0.38	0.60	0.54
33.	0.03	1.48	0.01	1.87	0.17	1.47	0.40	0.82
34.	0.10	0.33	0.12	0.22	0.49	0.42	0.63	0.58
35.								
36.	0.02		0.04		2.26		1.33	
37.	9.01	0.16	8.79	0.35	11.15	7.47	7.68	5.23
38.								
39.	0.18	0.00	0.16	0.16	0.52	0.48	0.65	0.62
40.								
41.	0.77	0.21	0.77	0.09	0.33	0.07	0.52	0.31
42.								
43.		0.83		1.12		1.20		0.62
44.								
45.	0.06	1.00	0.08	1.00	0.07	0.33	0.23	0.02
46.	0.49	0.23	0.45	0.42	0.28	0.28	0.49	0.47
47.		0.28		0.49		0.91		0.94
48.	0.06	0.31	0.08	0.52	0.92	0.71	0.94	0.79
49.	2.46	1.28	2.38	1.64	0.27	0.19	0.48	0.40
50.								

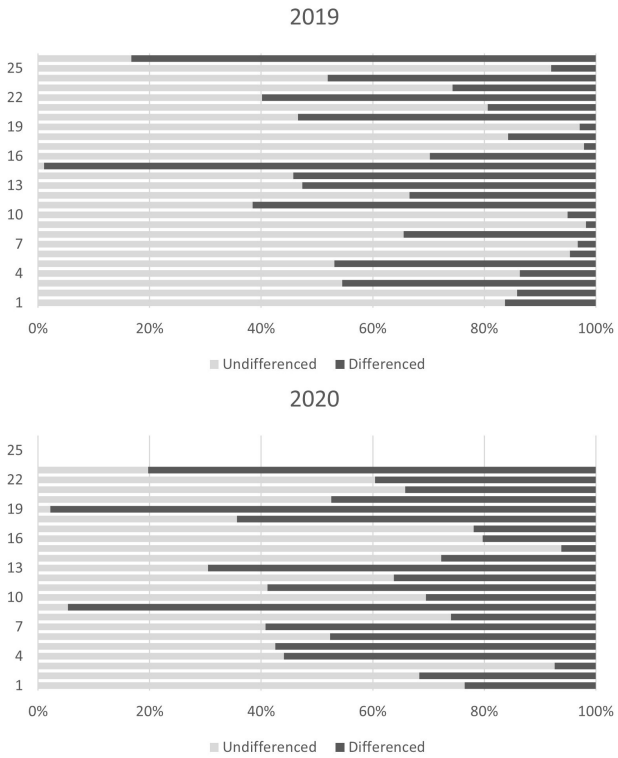

Fig. 3: A comparison of the ARD of each brewery (one per line) for the differenced (dark) and undifferenced (light) estimates at the aggregate industry multiplier level in 2019 and 2020 using a stacked graph to 100%

Tab. 13: Inputs to the calculation of private company discount (dimensionless)

	2019 median	**2019 aggr.**	**2020 median**	**2020 aggr.**	**FW2020 median**	**FW2020 aggr.**	**FW2021 median**	**W2021 aggr.**
EU public traded								
P/EAT	25.75	19.79	26.30	21.64	19.95	19.52	23.72	25.05
P/BV	2.05	2.20	2.70	2.36				
CZ privately held								
P/EAT	16.19	21.37	15.55	25.42	14.91	16.01	14.32	16.56
P/BV	1.16	0.98	0.81	0.94				
PCD								
P/EAT	37.13%	−7.96%	40.87%	−17.48%	25.29%	17.99%	39.61%	33.90%
P/BV	43.30%	55.62%	70.08%	59.94%				

Source: Damodaran (2020 and 2021), Drábek and Pastorek (2023).
Notes: Aggr. means aggregated, FW means forward and PCD represents private company discount.

AUTHOR'S ADDRESS

Michal Drábek, Department of Business Economics, Faculty of Business and Economics, Mendel University in Brno, Zemědělská 1, 613 00 Brno, Czech Republic, e-mail: xdrabek1@mendelu.cz (corresponding author)

Pavel Syrovátka, Department of Business Economics, Faculty of Business and Economics, Mendel University in Brno, Zemědělská 1, 613 00 Brno, Czech Republic, e-mail: pavel.syrovatka@mendelu.cz

DIGITALIZATION IN ENGINEERING FIRMS: THE ROLE AND IMPACT OF BUILDING INFORMATION MODELING ON PRODUCTIVITY

Gentjana Rexhaj[1]✉, Luboš Střelec[1]

[1] *Mendel University in Brno, Czech Republic*

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ABSTRACT

In recent decades, digitalization has become increasingly important in the construction industry. Building Information Modeling (BIM), a digital planning method, is becoming increasingly important in the infrastructure sector. Infrastructure planning implementation is complex, so engineering firms still use conventional planning. This study sheds light on the influence of Building Information Modelling (BIM) on increasing productivity in the construction industry. Through a combination of qualitative interviews and quantitative data analysis, an in-depth understanding of the implementation processes, challenges and benefits of BIM was developed. Particular focus was placed on identifying components of success for the effective implementation of BIM in infrastructure engineering firms. The results show that BIM contributes significantly to increasing efficiency by improving the accuracy of project planning, facilitating communication between project participants and reducing the error rate in the execution phase. The study emphasises the need for a clear strategy and training to fully exploit the potential of BIM and provides valuable insights for companies planning to implement BIM.

KEY WORDS

digitalization, Building Information Modeling, productivity, infrastructure planning

JEL CODES

A100, R420, R410, O320

1 INTRODUCTION

In recent decades, increasing digitalization has significantly changed several industries, including the construction industry. This evolution has particularly accelerated the adoption and application of Building Information Modeling (BIM), a pivotal tool in modern construction practices. This shift towards digitalization has spurred numerous new infrastructural network

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planning projects across different areas, with some already implemented and others in various stages of development or planning (Banister and Berechman, 2003). Such networks affect road construction and network structures for energy, civil engineering, and other utilities, which are becoming increasingly interconnected (Giannopoulos, 2014; Bertolini and Bevilacqua, 2006).

BIM is an advanced digital planning method that involves creating and managing digital models of structures. BIM is becoming increasingly important in the modern construction industry as it optimizes the planning and execution of construction projects. The construction industry increasingly relies on digitalized support to accompany such construction projects in planning, execution, and property management (Succar, 2009). In this context, engineering offices, utilizing modern digital tools like BIM for planning and executing construction projects, play an increasingly important role. Computer models or computer-aided planning structures are intended to help make planning more efficient in terms of costs, time, resources, and personnel deployment in all these projects (Eastman et al., 2011). In the infrastructure planning industry, digital technologies such as BIM could contribute to better project outcomes and greater sustainability (Borrmann et al., 2015). Especially in large projects with many trades, it is necessary to simplify the collaboration with various digital tools (Whyte and Lobo, 2010). To make this even more accessible and to make planning and execution even more efficient, a method is being used in some European countries and also worldwide in which "Building Information Modeling" forms the core of the entire planning process and is the basis for monitoring the construction project in all phases (Azhar et al., 2015; European Union, 2019).

Especially in building construction, BIM is applied throughout the whole construction process. BIM is a method or process in construction and design that involves the creation and management of a digital model of a structure (Porwal and Hewage, 2013; Sacks et al., 2018). Thus, BIM is an as-built model of a structure that contains various information, such as what materials were used or what part number the component has. In addition, a BIM model ideally also contains a schedule or information about the cost of the structures (Barbosa et al., 2017; Bryde et al., 2013). However, BIM still needs to be used to the same extent as in building construction in infrastructure construction, such as road, tunnel, or sewer construction. This is because the available BIM software is mainly suitable for building construction and less for infrastructure (Volk et al., 2014). Insights from Varvařovská and Staňková (2021) on the electricity sector's production possibilities may shed light on the intersections of digitalization and sector-specific challenges, potentially guiding varied BIM adoption across the industry.

In the infrastructure sector, 3D BIM models cannot be represented with the required accuracy, especially for linear structures such as roads. In addition, it still needs to be sufficiently clarified whether the BIM method is worthwhile for engineering firms in the infrastructure sector (Jun and Lee, 2010; Oti et al., 2016). Infrastructure construction has various service phases, some of which can be commissioned individually. Through BIM, there is a shift of effort into the early service phases, which can lead to more effort being invested in digital 3D planning than is subsequently remunerated (Succar et al., 2012; Smith, 2014). It is still to be clarified to what extent an optimized way of working can amortize the costs incurred by the new software. Amjad and Rehman (2018) point out, that the cost-effectiveness and productivity enhancements attributed to BIM could be deeply influenced by the caliber of e-information and the adeptness in adopting information communication technology. This accentuates the pressing need for a holistic scrutiny of the digitalization trajectory in civil engineering.

The primary aim of this manuscript is to explore the productivity of the BIM method in infrastructure planning via expert interviews and quantitative analysis and to work out initial recommendations for action or needs for action that can be useful for engineering offices to

optimize productivity with the BIM method. Given the relative lack of comprehensive studies examining the use of BIM in infrastructure design, there is an urgent need for this research. It aims to educate engineering firms about the potential benefits and challenges, and impacts of BIM adoption in infrastructure development (Cao et al., 2015; Howard et al., 1998). Building on this will shed light on the under-researched aspects of BIM's effectiveness, time management and financial impact on infrastructure design. This will help determine whether BIM, although proven effective in building construction, can achieve the same level of productivity in infrastructure (Sackey et al., 2014). It will also clarify whether long-term operational efficiencies and cost savings can offset the potential increase in initial costs and resources allocated to BIM implementation.

The article is organized as follows: Section 1 introduces the research topic and also the importance and background of BIM in infrastructure planning. Section 2 presents the current state of research and its implications in detail. Section 3 describes the methodology chosen for our study. In Section 4, we present our research findings, highlighting in particular the implications and challenges of BIM. In Section 5, we engage in a discussion that draws on the insights from our findings. Finally, the conclusions drawn from this work are laid out in the last section.

2 THEORETICAL FRAMEWORK

The construction industry has very complex planning, execution, and control phases; moreover, individual projects usually involve many different players. Errors in value creation, processes, and the quality of construction services frequently occur. In a US study, additional costs of around 4.3% were calculated for public construction projects that arose when processes were incompatible. In the USA, these annual costs amount to around 15.8 billion dollars (von Both et al., 2013). Efficiency requirements are increasing due to the constantly evolving competitive pressure. Improved coordination of planning and more efficient analysis processes can bring about a significant increase in efficiency (Strohe, 2013; Pereira et al., 2021).

In the European context, there are significant differences in the adoption and requirements of BIM. In Finland, BIM has been in operation since 2007, in the UK the use of BIM has been mandatory for government funded projects since 2016, which has led to a significant increase in BIM awareness and usage. In contrast, there is a high percentage of BIM users in Germany, but its use is not mandatory on all projects, with BIM being used on major projects. In France, although BIM is not required by law, it is still widely used, particularly in public projects and building construction. Spain and the Czech Republic have had active BIM programs since 2017 to achieve the introduction of BIM. Countries such as Poland and Austria are moving towards greater BIM implementation, with Poland planning to make BIM mandatory for state-funded construction projects by 2030. In Austria, it is already being used for budget control. Countries such as Croatia, on the other hand, are still lagging in the introduction of BIM and mainly use it in individual cases (PlanRadar, 2021; MagiCAD Group, 2020).

In a North American study by McGraw-Hill, which focuses primarily on the economic efficiency of BIM, experts confirm that an increase in efficiency can be achieved with the help of innovations in planning methods, technologies, and construction processes. In pilot projects of the McGraw-Hill study, time savings of around 50% were achieved in the USA, and some Scandinavian countries when the BIM method was applied in the planning and execution phase, and planning errors were significantly reduced (von Both et al., 2013). Furthermore, considerations regarding data governance and automated individual decision-making have also been shown to play a significant role in the efficiency and effectiveness of construction processes (Lăzăroiu et al., 2018). In this context, it

is worth considering the public administration's role in facilitating or impeding the implementation of new planning and construction technologies. Marišová et al. (2021) found that building offices in the Slovak Republic and the Czech Republic reported dissatisfaction with providing material, technical, and financial support from the state. This indicates the need for a supportive administrative environment to utilize innovative methods such as BIM effectively.

Existing studies often refer to building construction, e.g., large buildings, and not civil engineering measures, such as roads, pipelines, or other infrastructure measures. There is also a scientific gap in the economic viability of BIM for engineering companies in infrastructure and civil engineering. The BIM method should accompany the entire life cycle of a construction project – from the planning phase to the execution phase (König et al., 2016).

The application of BIM in infrastructure planning represents another relatively underrepresented dimension in current research. The specifics of infrastructure projects, particularly the linear nature of many, present unique requirements for the BIM methodology and its implementation. Moreover, the impact of BIM on the workflow within an engineering office still needs to be thoroughly understood. The transition to a BIM-centric approach signifies a significant shift in how engineers work and demands substantial training and adaptation (Cao et al., 2015; Howard et al., 1998).

Despite the paucity of extensive research in the field, certain studies have shown promising results. For instance, time savings and improved project delivery have been reported in cases where BIM was utilized effectively (Zhang et al., 2009). Several investigations also suggest BIM can contribute to cost savings in infrastructure projects. Arayici et al. (2012), for example, found that BIM's implementation in infrastructure planning led to cost savings due to fewer errors and reworks. Moreover, a growing body of research explores BIM's potential to improve sustainability in infrastructure projects. A study by Zhang et al. (2009) highlighted that BIM could aid in integrating sustainable design elements in infrastructure projects, potentially leading to environmentally friendlier results.

3 METHODOLOGY AND DATA

The main aim of this research is to answer the following research questions:

RQ 1: *How does the use of BIM methodology in infrastructure planning affect the productivity and efficiency of engineering firms?*

RQ 2: *What is the connection between BIM methodology and time management in infrastructure planning? Does BIM result in overall time savings, or does it increase the amount of time spent?*

RQ 3: *How does BIM use in infrastructure planning impact engineering firm costs? Are the initial costs and resources spent on BIM implementation offset by long-term operational efficiencies and cost savings?*

3.1 Qualitative Survey of BIM Experts

To address these questions, guided interviews with experts were used and evaluated with the help of content-structuring qualitative content analysis. The primary aim of conducting expert interviews is to obtain information by interviewing people identified as experts concerning an existing research interest. Expert interviews thus represent a method for generating qualitative data, which in text form forms the basis for subsequent analysis (Bogner et al. 2014). Moreover, these interviews provide rich, detailed insights that can lead to understanding the nuances and intricacies of BIM use in the industry, providing a depth of understanding that surveys and other methods might not achieve (Meho, 2006).

Respondents were carefully selected and included a broad range of 19 experts in the field, including ten engineers or drafters who use the BIM method, three trainers who help engineering firms implement and use BIM, four engineering firm executives, and two software developers who develop BIM software for infrastructure. It was ensured that all respondents had used the BIM methodology in infrastructure planning in their companies for several years.

In selecting the experts, engineers from the field of infrastructure planning were chosen who use the BIM methodology in their companies. In addition, software manufacturers from these areas and consultants from the areas of infrastructure and BIM were interviewed. In addition, managers and designers were interviewed. A total of 19 interviews were conducted. The guide comprises open-ended questions that allow for the most concrete and concise answers possible but to which the interviewees are free to respond. This comprehensive and diversified selection of experts ensures an array of perspectives on the BIM adoption, implementation, and challenges, providing a richer understanding of the subject matter (Fusch and Ness, 2015).

The interviews were transcribed and evaluated with the content structuring qualitative content analysis according to Kuckartz and Rädiker (2022). MAXQDA was used to analyze the expert interviews. The expert interviews were structured using multilevel categorization and coding, enabling a transparent, category-based evaluation of the individual aspects, resulting in a descriptive presentation of the results and a critical appraisal (Kuckartz and Rädiker, 2022). This method of analysis allows the discovery of patterns, themes, and categories within the data, which can lead to comprehensive and insightful conclusions about the productivity impacts of BIM (Saldaña, 2015).

3.2 Quantitative Data Collection and Analysis

In order to validate and expand the results obtained in the guideline-based expert interviews as part of this study, a quantitative research approach was chosen in accordance with the recommendation of Saunders et al. (2019), which enables the hypotheses derived from the expert interviews to be placed on a broader empirical basis and their generalisability to be tested.

In the quantitative phase of this study, an online survey was conducted. The sample size was limited to 66 participants due to the small number of BIM users in the field of infrastructure planning. This limitation resulted from the lack of a comprehensive database listing engineering firms that use both conventional and BIM-based methods in infrastructure planning. Participants were recruited primarily through the authors' network and by sharing the survey in specialised groups and professional social networks focused on BIM in infrastructure design. The not yet widespread establishment of BIM in this sector, compared to building construction, meant that some potential participants were reluctant to share their data and information. In order to focus the research on the planning of infrastructure measures, construction companies were excluded from the survey, which further limited the range of potential participants.

The questionnaire used in this study covered seven topics based on the findings from the qualitative expert interviews. In the first part of the questionnaire, demographic information was requested, including the number of years in the profession, the duration of involvement with BIM technologies, the proportion of BIM projects in the company and the size of the company in terms of the number of employees. In addition, the participants' position in the company was recorded, differentiating between roles such as project engineer, project manager, manager, BIM consultant, software manufacturer and others. These roles can be categorised into two main occupational groups: Consultancy and Planning. While the consulting group primarily supports engineering firms with

the introduction of BIM, the planning group focusses on the application of this methodology after its implementation. The integration of BIM consultants and software manufacturers into the study was deliberate, as these groups are actively involved in the BIM planning process.

The other topics from two to seven covered aspects such as obstacles (O), added value (AV), competition (C), investment (IC) and operating costs (OC), productivity (P) and time management (T) in relation to BIM in infrastructure planning. A five-point Likert scale was used for most questions, allowing respondents to express their agreement on a scale of 1 ("strongly disagree") to 5 ("strongly agree"). In the seventh topic area, specific questions were asked about the time saved by BIM, both in general and in various service phases. Participants were also asked to estimate the number of hours required for two hypothetical projects, one with and one without the use of BIM. These estimates were to be based on similar projects that had already been completed.

The data collection for this study was conducted using Unipark's online survey tool Tivian. When designing the questionnaire, care was taken to ensure that answering all questions was mandatory. This was to ensure that participants did not intentionally or inadvertently skip any questions. Despite this measure, in some cases incorrect answers were found in the final questions on the hours spent on various projects. These inconsistent or erroneous data were excluded from the analysis to ensure the integrity and reliability of the survey results.

The statistical software IBM SPSS was used to analyse the collected data. The first step involved a descriptive analysis of the data in order to identify basic trends and distributions. A factor analysis was carried out for question group 5 (costs) and divided into investment costs (IC) and operating costs (OC). Scales were formed from the mean values of the individual variables within the seven different question blocks, and t-tests and correlation analysis were applied on these scales. To check the reliability of the scales, Cronbach's α, a standard measure for the internal consistency of questionnaire items, was calculated. In addition, t-tests, correlation analysis and paired t-tests were included in the statistical analysis to investigate differences and relationships between different variables and to test hypotheses. This quantitative approach complements the qualitative findings and enables a more comprehensive understanding of BIM use in infrastructure planning.

In the expert interviews, different perceptions regarding obstacles, time management and investment costs in the use of BIM in infrastructure planning were identified between consultants and planners. The t-test was used as a method for analysing differences in order to examine these differences in more detail statistically. Before applying the t-test, the data was checked for normal distribution using Kolmogorov-Smirnov and Shapiro-Wilk tests to ensure the suitability of the t-test for data analysis. The t-test is a robust statistical method that makes it possible to determine significant differences between the mean values of two independent samples. This test is therefore used to analyse the following hypothesis 1: There is a significant difference between the professional groups consulting and planning in the perception of investment costs (H1.1), time management (H1.2) and obstacles (H1.3) incurred by BIM.

Following the findings from the qualitative expert interviews, which revealed different perceptions and opinions on the impact of BIM in infrastructure design, a correlation analysis was conducted to quantify the relationships between different aspects of BIM utilisation. This analysis was conducted using a non-parametric method and aimed to explore the relationship between key elements such as barriers to implementation, capital and operational costs, productivity gains and improvements in time management. The hypotheses for the correlation analysis were carefully formulated to test the qualitative insights derived from the interviews for statistical significance and strength of relationships. By combining this quantitative analysis with the qualitative data from the expert interviews, a more comprehensive picture

of the impact of BIM in infrastructure planning could be drawn. This integrated approach made it possible to place the hypotheses derived from the expert interviews on an empirical basis and to test their generalisability. This resulted in the following hypothesis 2: There is a significant correlation between the obstacles to the implementing BIM in infrastructure planning and investment costs (H2.1), between added value and operating costs (H2.2), between added value and time management (H2.3), between time management and operating costs in engineering firms (H2.4), between productivity and perceived improvement in competition (H2.5), between time management and productivity (H2.6), between added value and productivity (H2.7).

The qualitative expert interviews revealed different views on how effective BIM is in terms of time management in different project phases. In order to quantitatively substantiate these perceptions and to test whether BIM actually has a measurable effect on time management and in which phases this effect is particularly pronounced, a normal distribution was first tested and then a paired t-test was carried out. This test compares the time required for two specific infrastructure projects – the planning of bus stations and a 3100 m long road – both with and without the use of BIM. The corresponding questions in the questionnaire were aimed at determining the estimated hours required for these projects in different work phases, both for the year 2013 (without BIM) and for the year 2023 (with BIM). By comparing this data, it was possible to analyze whether and to what extent the introduction of BIM has led to time savings in the various phases of project planning. The paired t-test provides a robust methodology to test for significant differences in time spent between the two points in time. This analysis is crucial to understand in which phases BIM offers the greatest efficiency gains and whether these gains are consistent with the experts' perceptions from the interviews. For this reason, hypothesis 3 follows: The use of BIM in infrastructure planning leads to time savings if all service phases are commissioned.

4 RESULTS

4.1 Costs Arising from Digitalization and BIM

For a large number of experts, the costs incurred represent a challenge. With BIM, a new concept for quality management would have to be developed as the working methods and focal points change; the areas of responsibility for drafters and specialist engineers change. The exchange of information and cooperation is increasing, and the required IT landscape is also changing. New software systems are required, and higher costs arise when integrating the new way of working because the IT has to be adapted to the corresponding projects. Not every software solution can be applied to every project. Specific clients still require conventional 2D plans. With BIM, however, planning is usually done in 3D models, and these models often do not meet the requirements that cities and municipalities, in particular, have for their plans.

For this reason, flexibility in the working method is still required, which increases the cost of training new employees. The additional effort would often not be compensated by the customers, especially if the client does not require a BIM method. However, the request for BIM is increasing, especially for large clients or more significant measures, such as the construction of highways or large bridges. The rising costs and the complex integration would lead to substantial engineering offices using the BIM method, and thus small offices have only little chance to exist in the long term. In particular, the software manufacturers interviewed explain that large engineering firms benefit from a market advantage due to their capacities and use this to commission large BIM projects.

Nevertheless, the study results by Staniulienė and Lavickaitė (2022) underline the importance of providing adequate training and education opportunities for the successful implementation of BIM in infrastructure planning. By investing in skills development for employees and improving their BIM knowledge, companies can maximize productivity, reduce resistance to change, and achieve better project outcomes.

4.2 Effects of BIM on Time Management

The interviewees had very different opinions on the amount of time spent with BIM. Particularly in the first service phases, the time required increases significantly due to digitalisation with the BIM method, and it is precisely there that it is essential to have well-trained employees who work efficiently in these first service phases. One project manager describes that, for example, a draftswoman planning conventionally for over 20 years could produce a 2D plan within a very short time but would first have to be trained for a 3D design over a more extended period. For this reason, it is essential to be flexible in these first service phases when there is time pressure from the client, as one can then plan conventionally and achieve a result more quickly. The time required is also due to the lack of interfaces and data exchange; clients often cannot evaluate the results because they do not have the software. In addition, applying the BIM method primarily involves working with 3D models. The modeling of such models takes significantly more time, although 3D modeling is not always necessary in the early service phases, depending on the project. The software manufacturers interviewed report that it is a technical challenge for them to develop the software systems so that the workload for the specialist engineers does not increase. In addition, respondents report that experience shows that educating clients about the effort and options is significant in the early phases of performance. The respondents who state that BIM leads to time savings think that time savings only occur when the entire project is considered in all service phases and under the condition that the employees are trained. The software systems have been integrated into the way of working. Especially during the construction phase, there are many advantages because there are fewer errors in the planning due to the modeling in 3D, and in this way, there can be no construction stop. In addition, it is not so often necessary to adapt the planning quickly during the construction project because it has already been adopted by the BIM method.

Furthermore, a direct exchange on the construction site is possible, and necessary corrections can be discussed and adjusted promptly. Some clients only work with the BIM method, and some have their service and product catalogs, which the engineering offices can use for planning. Such product catalogs reduce the effort since they are components that no longer have to be modeled by specialist engineers. In addition, automated error checking means that the plans are not checked individually for errors, but this is done much more quickly via the software. Another point mentioned by the interviewees is that invoicing is faster and more accessible when the BIM method is integrated. In this way, invoices from construction companies can be checked more quickly. However, the engineering companies' invoices can also be made faster, which leads to further time savings.

4.3 Effects on Productivity in Engineering Offices

During the expert interviews, productivity was mentioned, particularly when a general question was asked. The interviewees were asked what generally comes to mind when they think of BIM or what they associate with the BIM methodology. Some mention that through digitalization with BIM, the understanding between the specialist planners improves so that the planning of other engineers can be understood more quickly. Some describe that the previous work is simplified by BIM (Fig. 1).

One software manufacturer describes that the expectations for digitalization with BIM are sometimes too high. Clients expect a complete solution with the BIM method that works

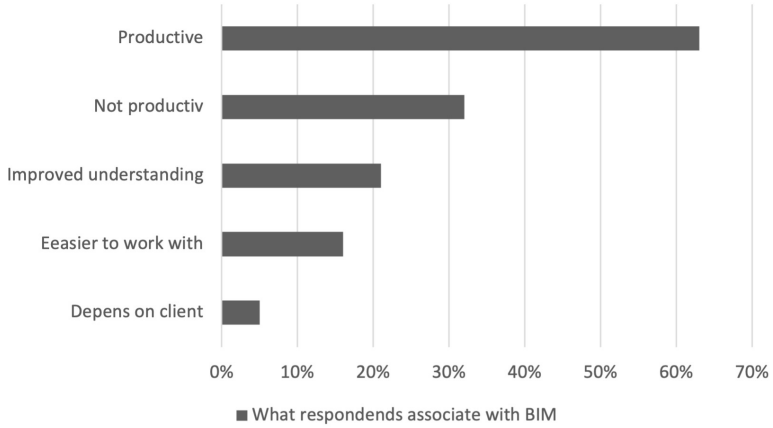

Fig. 1: What engineers associate with the BIM method in infrastructure planning

flawlessly and is directly applicable. In addition, there is a problem with the complete data exchange between different software solutions, for which there is currently no applicable interface. The data could only be displayed in another software to a limited extent; applicable solutions would still have to be developed here. Working with BIM is easier for some respondents because the software "thinks for itself." Thus it facilitates monitoring on the construction site because the 3D models can generate details at any point along the structures, which can be used to supervise and check the measurements on-site. Thus delays can be avoided. Some interviewees think that productivity is not improved by the BIM method; the effort would be about the same or even higher. More time would be invested in the modeling of the individual components. If a structure change is required, this is associated with an increased effort so that productivity decreases compared to the conventional method. For most respondents, the BIM method increases productivity, but this is highly dependent on the working method. Especially at the beginning, it is essential to plan with a low level of detail in order not to have too much effort. Since changes are often made at the beginning of planning, the client can also enter change requests directly on the model, which are analyzed by the specialist planners and processed quickly. If the comments on changes or errors are linked directly to the model, they can be corrected efficiently. Specialist engineers can, for example, digitally monitor tunnels or bridges via live transmissions and generate data from them. This leads to additional time savings, as engineers do not have to be continuously on-site at the structure and have more time to deal with problems. Digitalized simulations check whether the planned measure can be realized before construction begins. The number of employees and the construction machines required for the construction of the measure can be estimated more precisely, leading to efficient personnel management. Whereas with conventional planning, there were often situations in which different plans could not be merged without making changes. This occurs less frequently with 3D planning because the models are displayed in three dimensions from the start, and specialist planners ideally work in the same model. One project manager describes that operating costs are kept to a minimum, especially in collaborative projects.

4.4 Wider Benefits of BIM in Infrastructure Planning

The impact of BIM on time management and costs was considered from different angles, with many respondents seeing significant benefits of BIM in the context of infrastructure planning. Using BIM leads to a better understanding of the structure, better coordination, and better collaboration between project stakeholders.

This has led to a more harmonious, efficient, and effective project delivery process among the respondents. For example, engineers can better visualize complex measures with the BIM method. This understanding can help reduce errors in the design phase. By minimizing errors early on, engineering firms can avoid costly rework and changes later in the project. This advantage can be particularly beneficial in large infrastructure projects with numerous stakeholders and complex systems.

Similarly, BIM offers the potential for improved communication and collaboration. With BIM, engineers can coordinate their work more effectively with other stakeholders, resulting in a more streamlined and efficient planning process. In addition, BIM enables more transparent and effective communication with clients, as improved visualization allows them to understand the project better.

Another significant benefit of BIM is the existing potential to improve project management. With BIM, project managers can better track and manage project progress to ensure the project stays on time and within budget. They also have an overall view of the construction progress they can share with all project stakeholders. In this way, all project participants are on the same level of knowledge throughout the entire process. The 3D visualization BIM provides allows project managers to more accurately assess project status and identify potential problems before they become significant.

Although the benefits of BIM go beyond time and cost savings, its implementation requires significant investment, especially at the beginning of the roll-out and particularly in terms of staff training and IT infrastructure. Companies need to be prepared to incur these upfront costs and be aware that the full benefits of BIM may not be immediately apparent. According to experts, the true value of BIM only becomes apparent in the longer term as companies become more experienced with its use, and it becomes an integral part of their standard operating procedures.

4.5 Transition to BIM: Obstacles and Possible Solutions

The transition from conventional methods to BIM is challenging. Most respondents agreed that introducing BIM is a complex and lengthy process that requires financial investment and a high level of effort, time, and effort. The main barriers identified by respondents included a lack of staff knowledge and skills, resistance to change, and difficulties integrating BIM into existing systems and workflows.

Despite these barriers, respondents pointed to several possible solutions. These included continuous training and support for staff, developing clear implementation strategies, and fostering a culture of innovation and change within the organization. The need for broader industry and government support was also pointed out. This could include the development of industry-wide standards and guidelines, incentives for BIM adoption, and efforts to increase awareness and understanding of BIM across the industry.

In addition, respondents agreed that the successful implementation of BIM requires a holistic approach. It is not enough to simply buy BIM software; companies also need to invest in training their staff, upgrade their IT infrastructure and adapt their workflows and processes to take full advantage of the potential benefits of BIM. This requires a shift from viewing BIM as merely a tool to fundamentally changing how construction projects are managed and executed.

Although the transition to BIM can be challenging, with the right strategies and support, companies can overcome these obstacles and reap the full benefits of BIM. Respondents' experiences suggest that successfully adopting BIM requires strategic planning, ongoing training and support, and a willingness to innovate and adopt new working methods.

4.6 Quantitative Results: Detailed Analysis of BIM Effects in Infrastructure Planning

In order to determine the internal consistency of the various topics – obstacles, added value, competition, investment costs, operating costs, productivity and time management – the consistency coefficient Cronbach's α was used. Cronbach's α, a widely used coefficient for determining the reliability of data sets, varies between 0 and 1. A value close to 1 indicates high reliability, whereby it is generally assumed that values above 0.70 are considered acceptable (George and Mallery, 2003).

Scales were computed via arithmetic mean of variable manifestations. Reliability analysis yielded the following results: In the Obstacles section, one question was excluded from computation of the scale because we deemed corrected item-total corr. (0.088) too low. For the same reason one question each in the subject areas of competition and productivity was excluded from the computation of the corresponding scales (corrected item-total corr.: 0.225 and 0.184 respectively). Cronbachs α was deemed satisfactory for all scales. (H: 0.771; M: 0.895; W: 0.791; K_{1-4}: 0.852; K_{5-9}: 0.837; P: 0.710; Z: 0.838).

The Kaiser-Meyer-Olkin (KMO) test and the Bartlett test for sphericity were used to check the suitability of the data for the factor analysis. The KMO test, an indicator of sample size adequacy, yielded a value of 0.688, indicating moderate suitability of the data for factor analysis. According to Hutcheson and Sofroniou (1999), a KMO value above 0.5 is considered acceptable. With a χ^2 value of 303.830 and a significance level of $p < 0.001$, the Bartlett's test for sphericity showed that the correlation matrix of the items does not have the identity and is therefore suitable for factor analysis.

The subsequent exploratory factor analysis with a principal component method and a Varimax rotation with Kaiser normalisation led to the identification of two factors, which corresponds to the theoretical division into investment and operating costs. According to the scree plot, there was a clear kink after the second factor, which supports the selection of two factors. The principal component analysis with varimax rotation confirm this dichotomy: The first four questions load primarily on the first factor (IC), while the last five questions load primarily on the second factor (OC). This clear allocation of the items to the two factors confirms the underlying assumption that the cost structure in the context of BIM in infrastructure is two-dimensional.

In order to verify the assumption made in the expert interviews that the consulting and planning professional groups have different perceptions with regard to obstacles, time management and investment costs of BIM in infrastructure planning, a t-test for independent samples was carried out. Of the 66 study participants, 18 belonged to the consulting professional group and 48 to the planning professional group. For the application of the t-test, the normal distribution of the data was checked using the Kolmogorov-Smirnov and Shapiro-Wilk tests. The data of both groups showed only slight deviations from the normal distribution, as determined by visual inspection of the histograms.

The null hypothesis of the Levene test, that there are no differences in variance, could not be rejected in the area of investment costs ($p = 0.268$), which justifies the use of the t-test (Tab. 1). A significant difference (H1.1) was found between consultants (M = 2.667, SD = 0.809, $N = 18$) and planners (M = 2.062, SD = 0.768, $N = 48$) in the perception of investment costs through BIM, $t(64) = 2.807$, $p = 0.007$. Accordingly, there is a significant difference in the perception of investment costs through BIM between the professional groups of consulting and planning. It was found that planners are more critical of the investment costs of BIM in infrastructure planning than consultants. In the area of time management and obstacles, equal variances were not assumed after the Levene test. The results of the Welch's t-test are therefore reported. In the area of time management, there are significant differences (H1.2) in perception between consultants (M = 2.147, SD = 0.648, $N = 18$) and planners (M = 1.583, SD = 0.512, $N = 48$),

Tab. 1: Independent Samples Test

	Levene's Test for Equality of Variances		*t*-test for Equality of Means					95% Confidence Interval of the Difference	
	F	**Sig.**	**t**	**df**	**Sig. (2-tailed)**	**Mean Difference**	**Std. Error Difference**	**Lower**	**Upper**
IC*	1.250	0.268	2.807	64	0.007	0.60417	0.21523	0.17419	1.03415
T			3.324	25.363	0.003	0.56424	0.16974	0.21491	0.91357
O			2.723	23.805	0.012	0.45448	0.16692	0.10982	0.79913

Note: * Equal variances assumed.

Tab. 2: Spearman's Rank Correlation Coefficient ($N = 66$)

		O	**C**	**P**	**AV**	**IC**	**OC**	**T**
O	Correlation Coefficient	1.000	0.214	0.157	0.128	0.437**	−0.048	0.118
	Sig. (2-tailed)	.	0.085	0.207	0.306	0.000	0.700	0.345
C	Correlation Coefficient	0.214	1.000	0.488**	0.303*	0.276*	0.316**	0.362**
	Sig. (2-tailed)	0.085	.	0.000	0.013	0.025	0.010	0.003
P	Correlation Coefficient	0.157	0.488**	1.000	0.290*	0.270*	0.184	0.538**
	Sig. (2-tailed)	0.207	0.000	.	0.018	0.028	0.140	0.000
AV	Correlation Coefficient	0.128	0.303*	0.290*	1.000	0.136	0.629**	0.502**
	Sig. (2-tailed)	0.306	0.013	0.018	.	0.275	0.000	0.000
IC	Correlation Coefficient	0.437**	0.276*	0.270*	0.136	1.000	−0.034	0.259*
	Sig. (2-tailed)	0.000	0.025	0.028	0.275	.	0.788	0.036
OC	Correlation Coefficient	−0.048	0.316**	0.184	0.629**	−0.034	1.000	0.413**
	Sig. (2-tailed)	0.700	0.010	0.140	0.000	0.788	.	0.001
T	Correlation Coefficient	0.118	0.362**	0.538**	0.502**	0.259*	0.413**	1.000
	Sig. (2-tailed)	0.345	0.003	0.000	0.000	0.036	0.001	.

Note: Correlation is significant at the 0.01 (**) or 0.05 (*) level (2-tailed).

$t(25.363) = 3.324$, $p = 0.003$. This confirms the significant difference in the perception of time management of BIM between the professional groups consulting and planning. It is clear that planners perceive a more positive effect with regard to time management than consultants. In the area of obstacles, there are significant differences (H1.3) in perception between counsellors (M = 2.235, SD = 0.649, $N = 18$) and planners (M = 1.780, SD = 0.463, $N = 48$), $t(23.805) = 2.723$, $p = 0.012$. It becomes clear that the planners perceive more obstacles than the consultants.

In order to statistically verify the views identified in the expert interviews regarding the relationships between the analysed topics, a correlation analysis was carried out. The Pearson correlation analysis also assumes a normal distribution, which is assessed here using the Shapiro-Wilk test, the Kolmogoroff-Smirnov test and visual inspection of the histograms. The assessment shows that the assumption of bivariate normal distributions in the corresponding pairs of scales must be regarded as at least problematic. For this reason, the results of the non-parametric correlation analysis are presented using Spearman's ρ. The results for the correlations mentioned in the expert interviews are shown in Tab. 2.

The results of our study confirm significant correlations between various aspects of BIM in infrastructure planning. It is clear that there is a strong correlation (H2.1) between the obstacles to implementing BIM and the investment costs (Spearman $\rho = 0.437$, $p < 0.001$, $N = 66$). Furthermore, the results (H2.2) indicate that the added value resulting from BIM is related to the reduction of operating costs (Spearman $\rho = 0.629$, $p < 0.001$, $N = 66$). In addition, the results indicate a significant correlation (H2.3)

between the added value resulting from BIM and the improvements in time management (Spearman $\rho = 0.502$, $p < 0.001$, $N = 66$). The link (H2.4) between improvements in time management through BIM and the reduced operating costs is also confirmed (Spearman $\rho = 0.413$, $p < 0.001$, $N = 66$). In addition, the study leads to the assumption (H2.5) that the increased productivity through BIM is also linked to a perceived improvement in competition (Spearman $\rho = 0.488$, $p < 0.001$, $N = 66$). Although no clear correlation became apparent in the expert interviews, the quantitative analysis indicates that the improvements in time management through BIM correlate (H2.6) with increases in productivity (Spearman $\rho = 0.538, p < 0.001, N = 66$). It also leads to the conclusion (H2.7) that the perceived added value is related to the improvement in productivity (Spearman $\rho = 0.290$, $p < 0.001$, $N = 66$). These findings are particularly relevant in practice, they are an indicator that BIM not only poses challenges in terms of cost and implementation, but also offers clear advantages in terms of operating costs, productivity, competitiveness and time management.

During the expert interviews, it was reported that BIM leads to time savings if all service phases are commissioned, which is why this study collected data on the hours spent on two different infrastructure projects at two different points in time (2013 without BIM and 2023 with BIM). To examine the differences between planning with and without BIM, paired samples t-tests were carried out for the various service phases. For all pairs near normality in the mean differences was assumed. (Assessed via visual inspection of respective histograms). For the project of eight bus stations, the results indicate significant differences in the time required between the various work phases with and without BIM. For the early service phases (1–4) without BIM (M = 243.63, SD = 137.342) and with BIM (M = 268.27, SD = 137.919), a mean difference of 24.643 (SD = 48.701) was found, $t(55) = -3.787$, $p < 0.001$, $N = 56$. This indicates a significant difference. For the same project of eight bus stations and the entire service phases (1–9) without BIM (M = 387.38, SD = 235.406) and with BIM (M = 359.86, SD = 224.700), there was a mean difference of 27.518 (SD = 101.044), $t(55) = 2.038$, $p = 0.046$, $N = 56$. This also leads to a significant difference. In a further comparison, data is collected for a larger project, which is comparable to the construction of a 3100 m long road. The early service phases (1–4) without BIM (M = 749.62, SD = 226.400) and with BIM (M = 840.91, SD = 287.066) resulted in a mean difference of 91.291 (SD = 107.797), $t(54) = -6.281$, $p < 0.001$, $N = 55$. This also indicates a significant difference. For the same project and the entire service phases (1–9) without BIM (M = 1174.55, SD = 332.522) and with BIM (M = 1061.02, SD = 404.610), a mean difference of 113.527 (SD = 185.087) was found, $t(54) = 4.549$, $p < 0.001$, $N = 55$. This also indicates a significant difference.

These results indicate (H3) that the use of BIM leads to time savings for both small and large infrastructure projects when the planning service is commissioned throughout

Tab. 3: Paired Samples Test

					95% Confidence Interval of the Difference				
		Mean	Std. Dev.	Std. Error Mean	Lower	Upper	t	df	Sig. (2-tailed)
Project 1	Early Phases (1–4)	−24.643	48.701	6.508	−37.685	−11.601	−3.787	55	0.000
	Entire Phases (1–9)	27.518	101.044	13.503	0.458	54.578	2.038	55	0.046
Project 2	Early Phases (1–4)	−91.291	107.797	14.535	−120.432	−62.149	−6.281	54	0.000
	Entire Phases (1–9)	113.527	185.087	24.957	63.491	163.563	4.549	54	0.000

Notes: Project 1 – eight bus stations. Project 2 – 3100-metre road

the construction process (Tab. 3). However, the time savings identified vary depending on the project phase, which indicates the specific advantages of BIM in certain phases of project planning. These findings are consistent with the perceptions of the experts from the qualitative interviews, who emphasised the effectiveness of BIM in terms of time management in different project phases. The quantitative results emphasise the importance of using BIM for more efficient project planning and execution in the infrastructure sector.

5 DISCUSSION

The results of this paper contribute to the current literature on the productivity of engineering firms through the implementation of BIM. That the implementation of BIM leads to an increase in productivity in engineering firms is only partially consistent with the findings of previous publications. Similar to the present study, Succar et al. (2012) describes that BIM improves communication and collaboration, primarily through 3D models and other data that provide information about the entire life cycle of a building. This study found, through both expert interviews and quantitative data collection, that there are still challenges in integrating BIM into existing workflows and that investment in technology and training is required, a point also highlighted by Succar et al. (2012). He describes that staff training plays an essential role in effectively using BIM. In this study, however, it is clear that a change in working methods and corporate culture is required, especially for infrastructure measures. Thus, companies need to adapt their processes and structures to the new requirements to exploit BIM's benefits fully.

In line with the findings of Gerber et al. (2010) and Smith (2009), this paper can confirm that BIM contributes to improving productivity across the construction industry and can be used as a lean process to reduce waste and improve project quality, which is perceived as an added value by BIM users in the expert interviews as well as in the quantitative analysis. In the present study on current research, it becomes clear that engineering offices in infrastructure planning initially have high investment costs, which can be perceived as an obstacle and can act as a deterrent, especially for medium-sized and smaller engineering offices. Since Gerber have focused on the entire construction industry, the differences and details in the individual areas, such as the executing construction company, the engineering and architecture firms, and the other parties involved in the project, are not analyzed. Smith (2009), on the other hand, emphasizes the role of cost managers in implementing BIM, which can provide more certainty in implementing BIM.

This study also indicates that the improved productivity will change the competition for engineering firms. Experts report that companies that use BIM could be favoured by the methodology used, as the implementation of the BIM method also results in added value in terms of productivity for clients in the long term. Pan and Zhang (2020) describe a similar observation for construction companies. The use of BIM and the associated increases in productivity give them a competitive advantage. significant added value in terms of operating cost optimisation in the planning phase of infrastructure projects.

Barlish (2011) also concluded in case studies that applying BIM methodology leads to productivity improvements in engineering firms. The present study supports Barlish's conclusion that BIM can significantly reduce planning time. Some of the experts confirm the connection between the increase in productivity and the time saved with BIM in infrastructure planning, and this assumption is strengthened via quantitative analysis.

There is also a clear correlation between perceived added value and the resulting time savings. However, the study points out that this is only the case when BIM is used throughout the design process. Engineering firms only experience time savings if they are involved

in all service phases, as the effort required to design with BIM in infrastructure planning increases, especially in the early service phases. This is illustrated by the number of hours spent on the different service phases in this study. The remodelling of eight bus stations saves around 27 hours for the entire project if the project is commissioned in its entirety. The remodelling of a 3.1 km long road results in a time saving of around 114 hours. However, if only the first service phases are commissioned, the time required for both projects is higher. Shin et al. (2022), who compared real projects in a study on the use of BIM in railway construction and examined railway lines between approximately 1.7 km and 5 km in length, came to a similar conclusion. The results of Shin et al. (2022) show a time saving of around 103.5 hours compared to the conventional planning method. However, the study only considers rail transport and distinguishes between the data from three companies in each case. In his study, Shin et al. (2022) also describes a correlation between the time saved and the reduced operating costs. The study presented here also indicates a significant correlation between operating costs and time savings.

The expert interviews conducted revealed some different views between consultants and planners regarding the use of BIM in infrastructure planning. This observation led to further statistical analysis. The results of the present study indicate that the perceptions of consultants and planners differ in terms of challenges, investment costs and time management when applying the BIM method in infrastructure planning. A similar finding regarding different perceptions depending on professional groups was also made in the study by Rahmawati et al. (2019). This study implies that there are different views between consultants and managers in the architecture sector regarding the success factors of BIM. However, it should be noted that the study by Rahmawati et al. focuses on the architecture sector and primarily examines the factors that contribute to the success of BIM.

In the study by Olawumi and Chan (2019), a model is developed for improving project information management through BIM, so Olawumi and Chan do not consider BIM as a tool for a planning measure of a building, but primarily the management of BIM information and data, which has a positive effect on project control and project management in particular. The study by Rahman et al. (2016) also looks at the implementation of BIM and the associated change in the skills of project and BIM managers. On the other hand, this paper primarily considers the user-related view of BIM, i.e., particularly those planners and consultants who directly apply the software and methodology and already plan the measure as a 3D BIM model.

While the adoption of BIM has revolutionized insights and decision-making capabilities throughout the lifecycle, it is primarily focused on providing concrete data and lacks the ability to update information in real time without external data sources (Deng et al., 2021; Tang et al., 2019). The emergence of Internet-of-Things (IoT) applications and their integration with BIM models have enabled the emergence of the concept of the digital twin (Deng et al., 2021; Tang et al., 2019). Digital twins strive to synchronize the real world with a virtual platform, enabling seamless management and control of construction processes, building management and environmental monitoring. This represents a significant advance over BIM, as digital twins incorporate real-time data that enables dynamic visualization, analysis and automatic updating of models based on the real-time status of structures. However, the state of research in the field of digital twins is still at an early stage. It requires a deeper understanding for ongoing and future research, especially in the advancement of BIM to Digital Twins (Deng et al., 2021).

Regarding the limitations of our research, there might be some restrictions in the sample size and geographical coverage. Our sample focused on engineering companies in German-speaking countries, and therefore, the results might not be transferable to other geographical areas or other sectors of the construction industry; this limits the generalisability of the results. In addition, our results were based on self-reports by engineering firms, software vendors,

and training companies, which may lead to bias. Future researchers could encompass these issues by using a broader sample in German-speaking countries or beyond in several countries.

Conducting both a qualitative and a quantitative analysis offers a comprehensive approach. However, the sample size for the quantitative analysis is relatively small at 66 participants. This limitation was not only a reflection of the fact that the BIM method is not yet widely established and implemented in infrastructure planning and engineering firms but also due to practical constraints. Given the specific challenges in the adoption of BIM in infrastructure planning, it was neither feasible nor economically and timewise practical to reach a larger number of participants. Furthermore, some engineering firms that already use BIM in infrastructure planning are reluctant to share their knowledge in order to avoid increasing competition from other firms. Future research could therefore benefit from a broader sample in a European or international context.

In addition, future studies could investigate other aspects of BIM, such as its impact on collaboration and communication in construction projects or its influence on the environmental performance of buildings or infrastructure structures. As the use of BIM in infrastructure is still relatively new, there is significant potential for further research in this area. Further studies could also examine the long-term impact of BIM on productivity and efficiency in engineering firms and broaden the comparison with other industries. In particular, it could explore how BIM and other digital tools can contribute to improving sustainability and resilience in the construction industry. Finally, future research could also explore the development of best practices and guidelines for implementing and using BIM in different contexts to help companies realize the full potential of this technology. It would also be of interest to repeat this study at a later date when the BIM method has found wider application in infrastructure planning.

Further studies could also examine the long-term impact of BIM on productivity and efficiency in engineering firms and broaden the comparison with other industries. In particular, how BIM and other digital tools can contribute to improving sustainability and resilience in the construction industry could be investigated. Finally, future research could also explore the development of best practices and guidelines for the implementation and use of BIM in different contexts to help organisations realise the full potential of this technology.

6 CONCLUSIONS

The demand for digitalization, especially for BIM, is increasing in the infrastructure sector. However, small engineering firms, in particular, are shying away from the costs, training, and restructuring within the company, which can lead to small engineering firms being displaced by giant engineering firms. In addition, integrating the BIM method in the companies leads to a change in the fields of activity within the engineering offices. The demand for the profession of drafters, who in particular created 2D plans and supported engineers, may decline. To prevent this, it is essential that the training of drafters is adapted to the ongoing digitalization in the construction industry. In principle, the engineers' experience reports, in particular, agree that productivity increases across the entire BIM project but that the time invested in modeling the individual structures is higher than in conventional planning. To optimize productivity, according to the experts' statements, it makes sense to define requirements regarding planning with the client before starting the measure and to clarify the possibilities of the software systems and the methodology. To avoid the 3D models are not accepted by the client, it is necessary to define the level of detail of the digitized models before the start of planning. In this way, repeated re-planning into conventional 2D plans can be avoided, which requires renewed effort. In addition, flexibility in methodology can have a positive impact on

productivity. Certain representations can be shown more quickly via a sketch in 2D without the need for detailed clarification in 3D. This can result in further time savings by eliminating the need for additional modeling. Modeling can then take place after the client has approved the sketch. In this way, the BIM method can be used in a targeted manner and according to the situation. In principle, it can be said that BIM can optimize productivity under certain conditions. Since the 19 expert interviews are individual opinions, it is necessary to analyze productivity and cost-effectiveness via qualitative surveys and profitability calculations and to compare them with conventional planning methods. By combining individual perspectives from the 19 expert interviews with the findings from the quantitative analysis, it becomes clear that BIM in infrastructure planning has both productivity-enhancing and cost-intensive aspects, and further research is needed to enable a balanced assessment of the overall cost-effectiveness compared to conventional planning methods.

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AUTHOR'S ADDRESS

Gentjana Rexhaj, Department of Statistics and Operation Analysis, Faculty of Business and Economics, Mendel University in Brno, Zemědělská 1, 613 00 Brno, Czech Republic, e-mail: gentjana.re@gmail.com, ORCID: 0009-0003-1709-4736 (corresponding author)

Luboš Střelec, Department of Statistics and Operation Analysis, Faculty of Business and Economics, Mendel University in Brno, Zemědělská 1, 613 00 Brno, Czech Republic, e-mail: lubos.strelec@mendelu.cz, ORCID: 0000-0003-1556-0687

THE MEDIATING ROLE OF BRAND ATTACHMENT ON THE RELATIONSHIP BETWEEN BRAND EXPERIENCE AND CUSTOMER CITIZENSHIP BEHAVIOR

Amira Gamal Ahmed[1], Ahmed Yehia Ebeid[1],
Mahmoud Fawzy Mohamed[1,2]✉

[1] *Egypt-Japan University for Science and Technology, Alexandria, Egypt*
[2] *Damanhour University, Egypt*

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ABSTRACT

Despite substantial research on the antecedents of the relationship between brand experience and customer citizenship behavior, the effect of brand attachment remains a neglected subject in marketing research. Using social exchange theory (SET) and attachment theory, this study analyses the role of brand attachment as a mediator in the relationship between brand experience and customer citizenship behavior. Specifically, is to investigate the mediating role of brand attachment in the relationship between brand experience and customer citizenship behavior to clarify the role of the different dimensions of brand values among the customers of fast-food restaurants in Egypt. In this study, data was gathered through a questionnaire based on fast food restaurants. and for data analysis, structural equation modelling (SEM) was used. Findings reveal that customer citizenship behavior is directly influenced by brand experience. Furthermore, brand experience directly and significantly impacts brand attachment. Moreover, brand experience is a strong predictor of brand attachment, which promotes consumer citizenship behavior. The study finds that there is a partial influence on the relationship between Brand experience-consumer citizenship behavior relationship.

KEY WORDS

brand attachment, brand experience, customer citizenship behavior

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1 INTRODUCTION

In today's competitive and complex market, relational marketing seeks to build long-term consumer ties. However, building. Relationship between a brand and its consumer isn't always easy This relationship is not just governed by simply transactional incentives tied to utilitarian gains, it can be cognitive or emotional (Park et al., 2009; Thomson et al., 2005; Brakus et al., 2009; Grisaffe and Nguyen, 2011). In this context, the ability of brands to create

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lasting associations in the minds and hearts of their target customers is crucial to their success (Grönroos, 1995), which enhances the brand's ability to withstand competition due to positive consumer sentiments about the brand resulted from strong emotional connections (Kemp et al., 2014), and making the marketed brand their first choice when buying or consuming (Aaker, 1991; Keller, 1993; Wang et al., 2012). Previous research has helped brand managers gain a better grasp of how brand loyalty shapes consumer relationships (Kim et al., 2018). It is worth noting, however, that the study of brand citizenship has branched out into its field (Nyadzayo et al., 2015).

Customer citizenship behavior (CCB) stands for customer cooperative behavior, which is defined as "helpful, constructive gestures exhibited by customers that are valued or appreciated by the firm but not related directly to enforceable or explicit requirements of the individual's role" (Gruen, 1995, p. 461). Previous studies were done by Bowen (1986), Hsieh et al. (2004), and Keh and Teo (2001), who considered customers as part-time employees by providing their expertise.

Regarding this argument, companies can benefit from customers as human resources in improving the efficiency of an organization and service performance (Mills et al., 1983), productivity (Jones, 1990), and perception of service quality (Claycomb et al., 2001). Furthermore, a study by Bove et al. (2009) found that CCB affects attitude, loyalty, satisfaction, and brand equity. Additionally, it has been shown that CCB can have an effect on a company's bottom line and boost its brand's reputation and recognition among consumers (Van Doorn et al., 2010), brand' efficacy and strengthen a brand (Nyadzayo et al., 2015). First and foremost, CCB can improve a business's competitiveness (Matzler et al., 2015).

According to social exchange theory, customers who have benefited from businesses are likely to give back in kind (Groth, 2005; Payne and Webber, 2006; Xie et al., 2014). According to Grönroos (2011), customers who have positive brand experiences are more likely to assist the service provider and its other clients. Previous Studies indicate that providing consumers with experiences is the primary focus of companies (Accenture, 2015). The term "brand experience" is used to describe the emotional and behavioral reactions that brand-related stimuli elicit in consumers (Brakus et al., 2009). Consumers are more likely to have opinions about a brand after having direct contact with the brand via packaging, the brand name and logo, and other forms of marketing communication. Specifically, Brakus et al. (2009) identify four experiential dimensions – sensory, affective, cognitive, and behavioral – that contribute to how customers might affiliate with the brand. These dimensions help businesses cultivate long-term relationships with consumers (Fernandes and Moreira, 2019; Hwang and Kandampully, 2012) and strengthen brand attachment (Dolbec and Chebat, 2013; Forbes, 2016), which in turn influences customers' attitudes and behaviors, leading to favourable results for the brand (Thomson et al., 2005), such as brand loyalty (Park et al., 2010), customers' intentions to buy, willingness to pay, engage in word of mouth, and forgiving of brand missteps (Fedorikhin et al., 2008), and customers' extra-role behaviors (Assiouras et al., 2019).

Previous studies that investigated the relationship between brand experience and CCB used Brand community commitment (Aishah and Shaari, 2017), and brand relationship quality (Xie et al., 2017) as mediating variables between brand experience and CCB. To the best of the researcher's knowledge, the role of cognitive and affective bonds of brand attachment between these two variables (brand experience and CCB) was not examined. Hence, to address this research gap, The current study aims to examine the role of cognitive and affective bonds of brand attachment between brand experience and customer citizenship behavior CCB. Specifically, is to investigate the mediating role of brand attachment in the relationship between brand experience and customer citizenship behavior to clarify the role of the different dimensions of brand values among the customers of fast-food restaurants

in Egypt. Furthermore, this study aims to use a comprehensive measurement of brand experience and customer citizenship behaviors in one model. The model aims to include the four dimensions of brand experience (i.e., sensory, affective, behavioral, and intellectual) and the three aspects of customer citizenship behavior (i.e., feedback, helping and advocacy).

This paper is organized as follows: (1) a literature review drawing connections between brand experience, CCB, and brand attachment. (2) a discussion of the methodology utilized to collect data from a sample of 211 university students, and the results from structural equation modelling (SEM) analysis will be provided. Finally, the implications of the findings for theory and practice will be discussed.

2 THEORETICAL FRAMEWORK

2.1 Brand Experience (BE) and Customer Citizenship Behavior (CCB)

Brakus et al. (2009) defined brand experience as the subjective, internal responses of the consumer, including sensory, affective, cognitive, and behavioral experiences as the four dimensions of it that influence brand affiliation. The "sensory" component describes how consumers perceive brand and visual elements through their senses (Hwang and Hyun, 2012). This brand's aesthetic appeals to consumers' touch, sight, hearing, and scent (Brakus et al., 2009). According to Hwang and Hyun (2012), the "affective" component of experience comprises all the various forms of subjective experience that a consumer may have in conjunction with specific emotions and feelings. The "behavioral" component includes unique behavioral reactions to brand stimuli (Wang, 2014). Consumers are driven to participate in physical activities that provide memorable brand experiences (Wang, 2014; Kang et al., 2017). Finally, "intellectual" experiences spark consumer inquisitiveness and thinking (Schmitt, 1999a, 1999b).

CCB is a multifaceted term (Bettencourt, 1997), including feedback, advocacy, and assisting (Yi and Gong, 2013). Feedback is defined as "sincere information provided by customers about service quality that aids the organization in improving it" (Groth, 2005). As well as its customer service (Matzler et al., 2015). Advocacy involves endorsing a firm or employee to relatives and friends (Groth, 2005). Positive word-of-mouth advocacy improves product quality, corporate reputation, and market share among a wider client base (Groth, 2005). In a service co-creation process, "helping" refers to customers voluntarily assisting one another with the use of the service (Yi and Gong, 2013).

As noted by Thomson et al. (2005), attachment to a brand leads to beneficial brand outcomes, and CCB is one of them (Assiouras et al., 2019). This is supported by Bove et al. (2009) who argued that CCB has positive effects on attitude, loyalty, satisfaction, and brand equity. Based on the social exchange theory, Customers who have a positive brand experience are more likely to take part in additional, unprompted actions (Bettencourt, 1997), such as spreading the word and making positive recommendations about a company (Ferguson et al., 2010; Cetin and Dincer, 2014; Delgado-Ballester and Fernández Sabiote, 2015; Chelminski and Coulter, 2011; Loureiro and de Araújo, 2014) assist other customers and Report a service failure to the staff so that they may give solutions more quickly (Kim et al., 2018; Grönroos, 2011; Aishah and Shaari, 2017; Xie et al., 2017). In the food service industry, customers would engage in CCB when the brand reminds them of pleasant moments (Kim et al., 2018). In other words, brand-focused stimuli are indicated in food restaurants and consumers can experience a restaurant directly when buying and consuming its foods and services and indirectly through its communications and advertising (Brakus et al., 2009).

In this case, customers would seek out similar favorable brand experiences in the future

(Brakus et al., 2009), which in turn lead to increased CCB (Oliver, 1997). Hence, this study hypothesizes that:

H_1: Brand experience is positively related to customer citizenship behavior.

2.2 Brand Experience (BE) and Brand Attachment (BA)

Park et al. (2010) described brand attachment as "the strength of the bond connecting the brand with the self", it has two dimensions: brand-self connection and brand prominence. Attachment and the cognitive connections established between the individual and the brand form the basis of the concept of brand-self connection (Chaplin and John, 2005). According to Mittal (2006), consumers' attachment to particular brands serves as a form of self-definition. By making mental associations between the brand and the consumer, a sense of belonging is fostered. The degree to which a brand is remembered readily is referred to as its prominence (Park et al., 2010). Consumers are more likely to recall a brand's meaning when it strongly resonates with their values, needs, ambitions, and sense of identity, and when that meaning is strongly tied to their own experiences and personal memories (Gill-Simmen et al., 2018).

Social exchange theory (SET) explains the link between brand experience and brand attachment. People build and keep connections with others because they think it's in everyone's best interest, including the company's and the customer's (Blau, 1964). This is the core idea behind the SET. Customers who have a positive experience with a brand are more attached to that brand (Yu and Yuan, 2019; Mostafa and Kasamani, 2021; Tran et al., 2023; Chieng et al., 2022). According to Trudeau-Hamidi and Shobeiri (2016) and Park et al. (2010), there is a positive association between brand experience and brand attachment. This is because having a memorable experience with a brand helps to close the psychological gap that exists between the self and the brand. Thus, thanks to sensory, emotional, cognitive, and behavioral experiences, brands help people form meaningful memories (Shapiro and Spence, 2002; Krishna, 2012). Having access to this kind of memories relating to the brand may boost brand prominence (Chieng et al., 2022; Japutra et al., 2016; Park et al., 2010; Park et al., 2013; Trudeau-Hamidi and Shobeiri, 2016). Affective experiences indeed can alter one's temper and elicit strong feelings (Schmitt, 1999a, 1999b, 2012). One's connection to a brand may be affected by the feelings of excitement and pleasure one has because of these experiences (de Almeida and Nique, 2005; Schmitt, 2012). Additionally, studies done by (Chieng et al., 2022; Mostafa and Kasamani, 2021; Park et al., 2013; Schmitt and Zarantonello, 2013; and Trudeau-Hamidi and Shobeiri, 2016) have shown that having a positive experience with a brand can also contribute to cognitive and affective self-evaluation. Furthermore, Ramaseshan and Stein (2014) argued that consumer-brand relationship such as brand attachment, is the product of memorable, individual experiences with the brand that are retained in the minds of consumers and lead to brand loyalty (Brakus et al., 2009). Hence, we can hypothesize that:

H_2: Brand experience is positively related to brand attachment.

2.3 Brand Attachment (BA) and Customer Citizenship Behavior (CCB)

According to social exchange theory, CCB is influenced favorably by a high degree of customer-perceived value. Rather than being merely beneficiaries of the brand's resources, customers typically engage in proactive behavior such as investing and developing their resources to preserve their relationship with the brands that they consider to be their favorites (Jaakkola and Alexander, 2014).

According to Bove et al. (2009) and Lee and Kim (2022), customers who are attached to a brand engage in CCB toward a brand and other customers, and they are more likely to be willing to invest time and energy into preserving their relationship with that brand (Park et al., 2010). Tan et al. (2018) found that when a consumer has a high level of connection between a brand

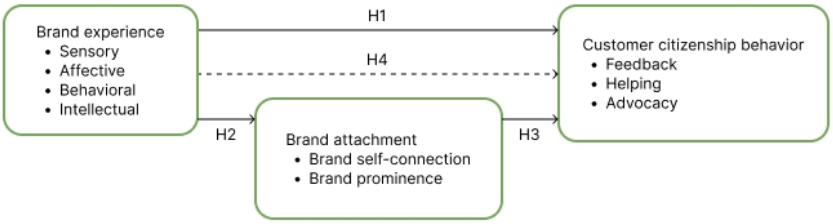

Fig. 1: Conceptual model

and themselves, they are more likely to develop a culture of care that connects other customers as well as employees. Furthermore, Thomson et al. (2005) argued that powerful emotions and thoughts that customers have about the service brand have a role in shaping their attitudes and behaviors. Thus, customers who feel a strong connection to a brand are more likely to promote it to others through positive word-of-mouth, testimonials, and recommendations (Sharif and Sidi Lemine, 2021; Moliner et al., 2018; Kemp et al., 2014). This demonstrates that customers are more likely to develop a strong emotional connection to a brand if they associate it with positive emotions and pleasant memories (brand prominence). As a result, high levels of brand engagement are to be anticipated (Thomson et al., 2005). So, the study can hypotheses that:

H_3: *Brand attachment is positively related to CCB.*

2.4 The Mediating Role of Brand Attachment (BA)

According to the social exchange theory, customers who have benefited from businesses are likely to reciprocate and be committed to a relationship with them (Groth, 2005; Payne and Webber, 2006; Xie et al., 2014). Bettencourt (1997) argued that customers who have a pleasant brand experience are more likely to take part in extra-role behaviors, such as making positive recommendations about a company and positive word of mouth (Ferguson et al., 2010; Cetin and Dincer, 2014; Delgado-Ballester and Fernández Sabiote, 2015; Chelminski and Coulter, 2011; Loureiro and de Araújo, 2014) helping and assisting other customers and providing feedback about the delivered service to staff (Kim et al., 2018; Grönroos, 2011; Aishah and Shaari, 2017; Xie et al., 2017).

Based on attachment theory, consumers who are strongly attached to a brand are more likely to consider it as irreplaceable because of their increased commitment to it (Park et al., 2010). Therefore, when consumers receive a pleasurable brand experience, they become more attached to the brand and have positive feelings about it (Belaid and Temessek Behi, 2011). In addition to this, previous research showed that the more consumers are attached to a brand, the more they are willing to engage in CCB (Park et al., 2010; Sharif and Sidi Lemine, 2021; Lee and Kim, 2022).

As presented earlier, a memorable and pleasurable brand experience resulting from customer–organization relationship leads to customer-brand attachment (Trudeau-Hamidi and Shobeiri, 2016; Park et al., 2010), which in turn makes customers more willing to elicit additional, unprompted actions (Bove et al., 2009; Lee and Kim, 2022). Hence, this study can postulate that brand attachment is a mediator between brand experience and CCB.

H_4: *Brand attachment mediates the relationship between brand experience and CCB.*

2.5 Conceptual Framework

This theoretical model is developed to shed light on the relationships between this study's variables. The key premise is that attachment to a brand cannot happen without a positive brand experience. Moreover, brand attachment is thought to be an important indicator of customer citizenship behavior. As a result, the relationship between brand experience and customer citizenship behavior may be significantly influenced by brand attachment (see Fig. 1).

3 RESEARCH METHODOLOGY

3.1 Philosophy and Procedures

This study followed a positivist research philosophy and undertook deductive reasoning using a quantitative approach with a survey method to deliver needed results. Quantitative research involves quantifying data which typically applies statistical analysis (Malhotra et al., 2017). Hence, as quantitative research is essentially about collecting numerical data to explain a phenomenon, questions seem directly appropriate to be answered using quantitative methods. This study was quantitative. The primary data was collected using a self-administered questionnaire. A survey was carried out to fulfil the purpose of this study, as well as to test its hypotheses and the model shown in Fig. 1. This study uses a convenient sample, that is consistent with previous studies using the same variables included in this study (Huaman-Ramirez and Merunka, 2019; Trudeau-Hamidi and Shobeiri, 2016; Kemp et al., 2014). It is applied to fast food restaurants as a response to a call from a study done by Kim et al. (2018), which argued that brand experience and CCB are apparent in the food service industry. Prior studies done by Huaman-Ramirez and Merunka (2019) and Trudeau-Hamidi and Shobeiri (2016), testing the same variables included in this study, collected data from the university students who participated in an online survey.

This analysis employs a convenient sample, which is consistent with prior studies (Huaman-Ramirez and Merunka, 2019; Trudeau-Hamidi and Shobeiri, 2016; Kemp et al., 2014). It is applied to fast food restaurants in response to a study conducted by Kim et al. (2018), which suggested that brand experience and CCB are visible in the food service business. Prior studies tested the same variables covered in this analysis (Huaman-Ramirez and Merunka, 2019; Trudeau-Hamidi and Shobeiri, 2016). The research strategy includes structural equation modelling (SEM) to analyze data. Before the main survey, a pilot study involving 55 participants helped to identify the fast-food brands capable of generating positive experiences and to test the reliability and validity of each of the scales.

3.2 Measures

All the survey questions came from previously published studies and were modified to fit the research environment when appropriate. On a scale from one (strongly disagree) to five (strongly agree), the respondents ranked how much they agreed or disagreed with each statement using a five-point scale. According to Brakus et al. (2009), the measurement of brand experience included four sub-dimensions: the sensory experience, the emotional experience, the cognitive experience, and the behavioral experience, with three items for each experience. a scale established by Park et al. (2010) used to measure Brand attachment. This scale consisted of two dimensions: brand-self connection and brand prominence. Helping customers, advocating, and offering feedback were the three components that were included in the scale of CCB that was designed by Yi and Gong (2013).

4 RESULTS

Following the methodology used in the literature (Malär et al., 2011; Park et al., 2010), respondents are asked to select from a list of fast-food brands the one with which they have the most positive experience. Then, they were asked to complete the survey with the selected brand in mind. The questionnaire was sent to 211 students. The sample has the following demographic profile: gender (female 63.5%, male 36.5%); the majority (55.4%) of the respondents are frequently eating in fast food restaurants once a month (see Tab. 1).

Tab. 1: Demographic characteristics of the sample

Item	Frequency	Percentage (%)
Gender		
Female	134	63.5
Male	77	36.5
Total	211	100.0
Frequency of eating in brand X		
Once a month	117	55.4
Twice a month	55	26.1
Three times or more	39	18.5
Total	211	100.0

To examine the connections between the latent and observable variables, this study employs confirmatory factor analysis (CFA) with AMOS 24.0. The proposed model was tested using structural equation modelling (SEM). Root means square approximation (RMSEA), comparative fit index (CFI), normed fit index (NFI), and Tucker-Lewis's index (TLI) were employed to evaluate the study model's goodness of fit. Then, the values of the Average extracted variance (AVE), the Composite Reliability (CR), and the standardized loading of terms and dimensions are presented. Finally, the study's discriminant validity was tested. The results of the CFA in Tab. 2 showed that the values of CFI, TLI, NFI were all higher than the specified standard (Hair et al., 1998; Hu and Bentler, 1999), where all their values are greater than (0.9), and the value of RMSEA is less than (0.06).

Tab. 2: The results of model fit measurements

RMSEA	TLI	NFI	CFI	p-value
0.05	0.90	0.90	0.902	> 0.01

Campbell and Fiske (1959) provided two criteria for determining the construct validity of a test. Convergent validity – the degree of confidence that a trait is accurately measured by its indicators. Discriminant validity – the degree to which measures of different traits are unrelated. Confirmatory Factor Analysis has traditionally been used in structural equation modelling, to assess construct validity. In a Confirmatory Factor Analysis convergent and discriminant validity examine the extent to which measures of a latent variable share their variance and how they are different from others. According to this criterion, the convergent validity of the measurement model can be assessed by the Average Variance Extracted (AVE) and Composite Reliability (CR).

Tab. 3: List of measurement items, factor loading, CR and AVE

Items	Factor loading	t-value	Sig	AVE	CR
X				0.520	0.764
X_1	0.672	7.941	> 0.01		
X_2	0.77	8.174	> 0.01		
X_3	0.717	constant	> 0.01		
X_4	0.598	6.346	> 0.01	0.453	0.707
X_5	0.832	7.253	> 0.01		
X_6	0.557	constant	> 0.01		
X_7	0.652	8.522	> 0.01	0.516	0.760
X_8	0.784	10.024	> 0.01		
X_9	0.711	constant	> 0.01		
X_{10}	0.702	9.167	> 0.01	0.588	0.809
X_{11}	0.882	8.888	> 0.01		
X_{12}	0.701	constant	> 0.01		
M				0.611	0.862
M_1	0.783	constant	> 0.01		
M_2	0.803	12.472	> 0.01		
M_3	0.834	13.003	> 0.01		
M_4	0.701	10.537	> 0.01		
M_5	0.792	constant	> 0.01	0.511	0.806
M_6	0.763	10.679	> 0.01		
M_7	0.636	9.357	> 0.01		
M_8	0.647	9.485	> 0.01		
Y				0.50	0.749
Y_1	0.730	constant	> 0.01		
Y_2	0.649	7.678	> 0.01		
Y_3	0.738	8.335	> 0.01		
Y_4	0.782	constant	> 0.01	0.534	0.820
Y_5	0.766	8.409	> 0.01		
Y_6	0.718	8.783	> 0.01		
Y_7	0.650	8.892	> 0.01		
Y_8	0.835	constant	> 0.01	0.695	0.872
Y_9	0.859	13.684	> 0.01		
Y_{10}	0.806	12.885	> 0.01		

Tab. 4: Discriminant validity

	X_A	X_B	X_C	X_D	M_A	M_B	Y_A	Y_B	Y_C
X_A	(0.721)								
X_B	0.652**	(0.673)							
X_C	0.466**	0.508**	(0.718)						
X_D	0.485**	0.457**	0.721**	(0.766)					
M_A	0.379**	0.422**	0.579**	0.635**	(0.781)				
M_B	0.405**	0.470**	0.540**	0.588**	0.777**	(0.714)			
Y_A	0.353**	0.254**	0.253**	0.306**	0.358**	0.405**	(0.707)		
Y_B	0.256**	0.230**	0.217**	0.323**	0.364**	0.340**	0.441**	(0.730)	
Y_C	0.496**	0.475**	0.282**	0.387**	0.413**	0.457**	0.417**	0.374*	(0.833)

AVE measures the level of variance captured by a construct versus the level due to measurement error, values above 0.7 are considered particularly good, whereas the level of 0.5 is acceptable. CR is a less biased estimate of reliability than Cronbach's α, the acceptable value of CR is 0.7 and above (Alarcón and Sánchez, 2015).

Tab. 3 presents the values of CR and AVE as well as the factor loading. The t-value shows that all Standardized loading for the expressions is statistically significant, at a significance level < 0.01. All values of the Standardized loadings for the expressions are appropriate, as they were all greater than (0.5). The composite reliability (CR) indicators are high, above the threshold value of 0.7 (Hair et al., 2006). It is clear from the table that all AVE indicators are appropriate (above or equal to 0.5). Therefore, they are considered acceptable values. Thus, confirming the convergent validity of the scales (Bagozzi and Yi, 1988).

The square root of AVE values for each variable is greater than the values of the correlation between it and the rest of the variables, presented in Tab. 4, which indicates the acceptable level of discriminatory validity for the variables (Gefen et al., 2000). Further evidence, the correlation coefficient between the components is less than 0.90, indicating a moderate correlation between the elements that improve discrimination of the factors from each other, referring to discriminant validity.

Amos' confirmatory factor model is presented in the following diagram (see Fig. 2) for the study variables. Where large ovals indicate the study's variables (brand attachment brand experience and customer citizenship behavior), while smaller ovals indicate measurement errors. The arrows indicate the connection between the variables of the study. The single-directional arrows emanating from the variables to the rectangles (which represent the indicators that are measured) indicate the paths of each specific group of items and the measured indicators on the factor to which they belong.

The structural equation model is used to test the study model and its hypotheses (Hair et al., 1998). The results in Tab. 5 showed that brand experience significantly influenced CCB ($\beta = 0.262$, t-values $= 12.841$, $p < 0.05$) and brand attachment ($\beta = 0.663$, t-values $= 3.438$, $p < 0.05$), supporting H_1 and H_2. Furthermore, brand attachment had a positive significant effect on CCB ($\beta = 0.353$, t-values $= 4.630$, $p < 0.05$), thus H_3 was supported. When brand attachment was inserted as a mediator between brand experience and CCB, BE was still significant ($\beta = 0.234$, $p < 0.05$); hence, brand attachment partially mediates the BE and CCB association, thus supporting H_4.

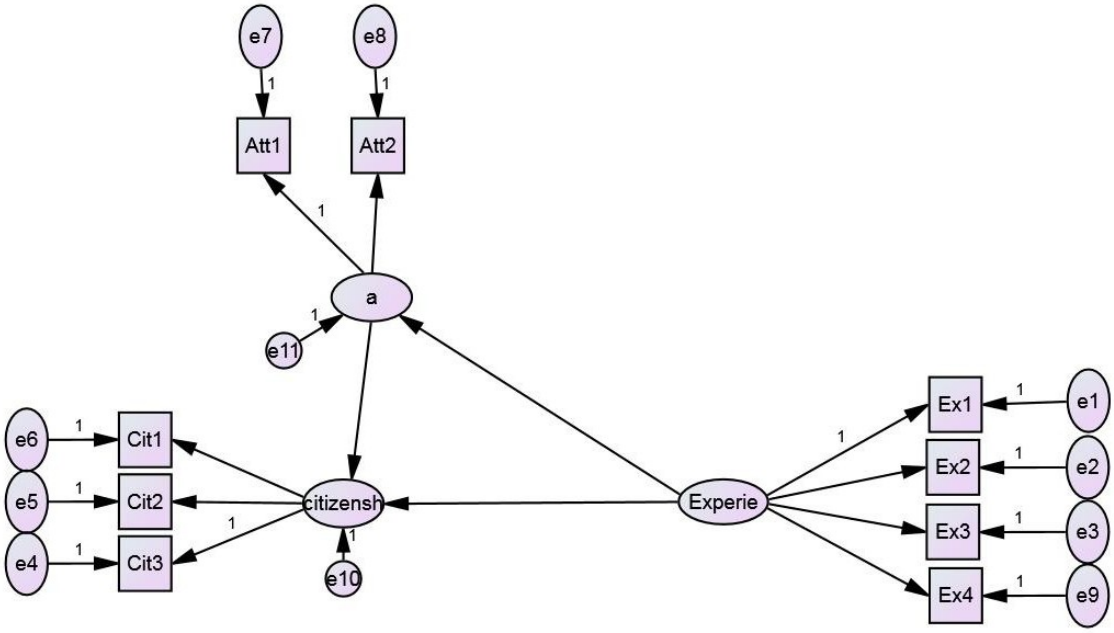

Fig. 2: Amos Confirmatory factor model

Tab. 5: Result structure equation model test

	Path	Estimate	t-value	SE	Sig
H_1	Experience → CCB	0.262	12.841	0.072	Sig
H_2	Experience → Attachment	0.663	3.438	0.079	Sig
H_3	Attachment → CCB	0.353	4.630	0.057	Sig
H_4	Experience → Attachment → CCB	0.234			

5 DISCUSSION

The main objective of this research is to investigate the role of brand attachment in the relationship between a brand experience (BE) and customer citizenship behavior because of ignoring its role and focusing on other mediating variables (Aishah and Shaari, 2017; Xie et al., 2017). The results of the data analysis were novel. H_1 is supported by the fact that BE has a direct, significant effect on the CCB. This is in line with findings from previous studies such as Kim et al. (2018) and Xie et al. (2017). Hence, this demonstrates the significance of providing a unique experience at every point of contact between a brand and its target audience. Second, the findings confirmed H_2 and showed that a positive brand experience has a direct and substantial effect on brand attachment. This agrees with the findings of prior researchers: Chieng et al. (2022), Schmitt (2012), and Tran et al. (2023). Consequently, the findings support H_3 by showing that BE is a fundamental predictor of brand attachment, which in turn encourages consumer citizenship behavior. This finding is also consistent with Park et al. (2010) indicating that when a customer has a strong attachment to a product or service, they are more likely to devote resources, time, and energy, into the relationship to keep it going. On the other hand, our research finding is partially consistent with the study done by Lee and Kim (2022) which indicated that only brand prominence significantly influenced

CCB but not for self-brand connection. The findings also supported H_4: brand attachment partially mediates the BE-CCB association. As a result, this discovery provides crucial insight into how consumers' emotional and cognitive responses to various brand-related stimuli (such as brand characters, packaging, and layout design contribute to their attachment to that brand, which further makes them more eager to engage in CCB.

5.1 Theoretical Implications

Several theoretical contributions are made by this study to the marketing literature. First, Prior researchers have studied the relationship between BE and customer citizenship behavior, but they have neglected the role of brand attachment as a mediator of this relationship. This study adds to the existing literature by investigating the impact of BE on the cognitive and affective ties that customers have with their preferred fast-food brands, and how this, in turn, affects the citizenship behavior of these consumers. Therefore, this study makes a theoretical and empirical contribution by proposing and testing, for the first time (to the best of the researcher's knowledge), a relationship between BE and consumer citizenship behavior via brand attachment. Second, this research makes an important new addition to the existing body of literature on branding and expands our understanding of the customer–brand relationship and the BE–CCB association by shedding light on the fundamental role that attachment plays in branding and its function as a fundamental mediator in the relationship between BE and CCB. Finally, this study establishes that customers' cognitive and affective ties towards the brand can be major antecedents to their extra-role behaviors (Park et al., 2010).

5.2 Practical Implications

The current study provides valuable information that can be used by marketing managers who are attempting to build long-term relationships with customers of fast-food restaurants and strengthen their brands. The current study's findings could help to improve customer citizenship behaviour in the fast-food restaurant industry. Fast food managers may focus on customer relationship management concerning the four dimensions of brand experience and attempt to develop a brand relationship with customers. Because brand experience has been determined to have the greatest impact on brand relationships.

First, experiential brands are crucial to consumers' extra-role behaviors, therefore fast-food brand managers should promote and build holistic BEs to maintain strong customer relationships. Customers who are attached to the brand are more likely to voluntarily aid other customers, recommend the brand to others, and provide feedback to the brand. Managers need to be aware of this fact to properly manage their properties. To be more specific, this refers to the favorable memories and thoughts that a customer has towards the brand and the service that it provides. This can be done by communicating the brand's personality, history, and stories externally through developing brand platforms. Second, businesses should establish cognitive and affective links with consumers through means such as developing marketing initiatives that arouse consumers' feelings of warmth and a sense of belonging and boost their sense of identification with and recall of the brand. As well as designing experiences that are continuously in line with the desires and priorities of the target market. Third, experiential branding should be prioritized as it influences clients' buying decisions when customers encounter various brand stimuli, such as brand-related shapes, layout, colors and design, slogans, salespeople, events, etc. In addition, fast food organizations are advised to allow their consumers to participate in more fast food-related activities, increasing interactions between customers and marketers or staff. Furthermore, Fast food managers should deliver a customized fast-food service to facilitate client reaction for an effective brand experience. Finally, marketing managers should convey the desired experience internally to create a shared vision and instruct staff on how to choose

ambient conditions (music and aroma) and outlet design (signs and lighting). Fast food restaurants can communicate their philosophy by providing unique symbolic philosophy, and entertainment activities to make it easier for customers to attach to the brand and its distinguished position in the industry.

In addition, encourage client participation in service delivery by providing suggestions for healthy food menus or suggestions for green restaurant premises. Frontline personnel should also receive training to improve their customer service skills and to make quick decisions when solving client difficulties and ensuring their satisfaction.

5.3 Limitations and Further Research

This research has several Limitations. Firstly, a convenience sample limits our study, so generalizing the results should be done with caution. Secondly, if the research used cross-sectional data, a longitudinal investigation would be ideal. Thirdly, the sample was collected in Egypt. Thus, collecting data from other nations to test hypothesized relationships could improve future research studies. Finally, this study solely covered fast food brands. The model could be tested in different sectors.

5.4 Conclusion

This research aimed to investigate the role of brand attachment in the fast-food brands that mediate the relationship between BE and CCB. The findings provided support for the hypothesized linkages and enhanced the importance of BE in the process of initiating brand attachment, which will ultimately result in CCB. In particular, the results showed that customers are inspired to participate in CCB after having a positive experience. Experiential brands also endorse consumers' self-connection and foster a feeling of affection for the brand by appealing to their emotions and thoughts. Additionally, the findings have important theoretical implications, as the study contributes to the BE-CCB literature by investigating the mediating role of brand attachment. The research also offers brand managers recommendations for creating an unforgettable brand experience that strengthens customers' emotional and cognitive connections to the company.

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AUTHOR'S ADDRESS

Amira Gamal Ahmed, Faculty of International Business and Humanities, Egypt-Japan University for Science and Technology, Alexandria, Egypt, e-mail: amira.gamal@ejust.edu.eg

Ahmed Yehia Ebeid, Faculty of International Business and Humanities, Egypt-Japan University for Science and Technology, Alexandria, Egypt, e-mail: ahmed.yehia@ejust.edu.eg

Mahmoud Fawzy Mohamed, Faculty of International Business and Humanities, Egypt-Japan University for Science and Technology, Alexandria, Egypt; Faculty of Commerce, Damanhour University, Egypt, e-mail: mahmoud.fawzy@ejust.edu.eg (corresponding author)

PERSPECTIVES OF FARM DEVELOPMENT UNDER THE WAR CONDITIONS IN UKRAINE

Volodymyr Anatoliiovych Kolodiichuk[1]✉, Ivan Mykolaiovych Tofan[2], Iryna Anatoliivna Kolodiichuk[3], Igor Volodymyrovych Voronyj[1]

[1] *Stepan Gzhytskyi National University of Veterinary Medicine and Biotechnologies, Lviv, Ukraine*
[2] *Lviv National Environmental University, Dubliany, Ukraine*
[3] *Dolishniy Institute of Regional Research of NAS of Ukraine, Lviv, Ukraine*

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ABSTRACT

The article discusses the existing structure of agricultural production in Ukraine and defines the key role of farmers in providing the population with food products at the beginning of a full-scale war. The high adaptability of the small goods sector of the agrarian economy and insufficient attention to its development in the pre-war period have been proven. An assessment of the main challenges, general losses and measures taken regarding the development of agriculture in Ukraine during the war period is given, and the importance of international financial support is emphasized. The need for a balanced model of the corporate and small commodity sectors development in the postwar period with a change in priorities to support small farmers is emphasized. It is proposed to develop a National Action Plan for the Development of Farming, which should be an integral part of the post-war reconstruction plan for Ukraine.

KEY WORDS

farm enterprises, martial law, National Action Plan for the Development of Farming, compensation for losses, international financial support

JEL CODES

D20, Q13, Q18

1 INTRODUCTION

The Ukrainian agricultural sector is a strategic sector of the national economy which contributes a significant share of the state budget and ensures the country's food security. The evolutionarily formed structure of agricultural production in Ukraine, consisting of the corporate and small commodity sectors, with the beginning of a full-scale war witnessed the strengthening of the tendency towards stagnation of large agricultural holdings and

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other agrarian companies while the role of farmer-owned and private family-run farms has grown. According to the United Nations, in 2021 farms in the developed countries of the world produced more than 85 percent of the agricultural products volume, while in Ukraine this indicator barely reached 10 percent of GDP, having decreased by 4 percent compared with 2020 (Odarchenko, 2023). Moreover, in contrast to Ukraine, the main trend in the West is the development of small farms. According to Food and Agriculture Organization of the United Nations (2016), about 97 percent of all farms in the EU-28 should be considered family farms. The Netherlands has the largest share of such farms – 98 percent. In neighboring Poland, this number is 90 percent. As of 2016, in the EU-28, only 27.5 percent of the area was cultivated by corporate farms, and the majority of the rest – by family farms.

Despite the pre-war successes in the production and export of products (Kolodiichuk, 2020) of the corporate segment of Ukrainian agriculture, Russia's aggression significantly complicated the functioning of agricultural holdings due to a significant loss of control over the production system, as well as the breakdown of logistics chains, catastrophic material losses and losses of fixed assets, environmental disasters on corporate livestock complexes and poultry farms, blocking of sales markets, etc.

According to preliminary estimates by scientists, by the beginning of September 2022, the potential direct damage caused to the country's agricultural infrastructure and assets as a result of Russia's full-scale aggression against Ukraine exceeded 6 billion dollars. Instead, farmers and private farms have demonstrated their key role in the preservation and development of local markets and food supply chains and have become a reliable source of providing the population with agricultural products and food.

Before the full-scale war started, agricultural holdings and large agricultural enterprises with a significant foreign capital share, oriented towards constant monoculture expansion and export effectively monopolized state support for the entire agricultural sector in Ukraine. Despite high incomes from the main activity and having a powerful lobby in the state authorities, 5–10 percent of the largest agricultural enterprises of Ukraine before the war concentrated 70–80 percent of the national funds allocated for the agriculture support (National Academy of Science of Ukraine, 2022). In addition, these subjects, meeting certain criteria, received significant investment resources from such institutions as the World Bank, the International Monetary Fund, the European Bank for Reconstruction and Development, and also had more opportunities for borrowing from the national banking sector.

At the same time, the incomes of agricultural holdings are taxed according to a simplified system, and a significant amount of income is absorbed through offshore zones, which negatively affects the formation of budgets at various levels and causes minimization of expenditures on social programs (Yatsiv and Kolodiichuk, 2018). All these aspects of the agricultural holdings functioning lead to unfair competition with farmers and family-owned farms, and, obviously, the post-war agrarian policy of Ukraine requires a review of the priorities of structural development on the basis of ensuring equal conditions for all economic entities, regardless of ownership form and production scale.

2 THEORETICAL FRAMEWORK

Implementing the model of post-war balanced structural development of agriculture in Ukraine, in the article, we focus on the prospects for the development of family farms, which are the weakest link in the national agricultural structure, as agricultural holdings have largely adopted Western models of management, use a wide range of investment resources, and are sufficiently efficient. Balanced structural development is also relevant in the context

of the lifting of the moratorium on the sale of agricultural land from 1st July 2021 as the future model envisions a change in agricultural policy to be based on fairness and providing equal opportunities for all participants in the agricultural production, including transparent and fair access to agricultural and other land, production resources, free access to sales and competition on a fair basis.

3 METHODOLOGY AND DATA

To achieve the article goal, we solved the following tasks: using the dialectical method of knowledge of objective reality and the comparison method, evaluate the state and conditions of development of agricultural and personal farms. Systematization and grouping of problems that arose from unprecedented military challenges and state neutralizing actions precede the critical adoption of decisions regarding the prospects for development of the small-scale agricultural sector. The monographic method of study of the activities of economic subjects was used in the context of existing problems, and the abstract-logical method of research was used to formulate the results and proposals of scientific research.

The methodological basis of our research is the use of alternative approaches to gathering information and estimating problems under the conditions of full-scale war. The lack of systematic statistical information on agribusiness throughout the territory of Ukraine requires the search for sources of analytical and empirical data by analyzing cases and comparing the opinions of civilian and military experts, national institutional structures and authoritative international organizations. The main difficulties are connected with the estimation of the front-line and temporarily occupied territories of Ukraine. For the objectivity of the estimation of agricultural production, we will use, in particular, the methods of applying satellite data of Earth observation to benefit food security, agriculture, and human and environmental resiliency in the US and worldwide of the NASA Global Consortium for Food Security and Agriculture – NASA Harvest. This organization estimates the production of major grain and oilseed crops, both in controlled and temporarily occupied territories, using methods based on satellite data to obtain these estimates. NASA Harvest research will help us understand the real situation regarding crops and the general state of production in the temporarily occupied territories, and it is an important tool for estimating the nature and scale of agricultural activity under occupation. Satellite information, especially when combined with economic data, is being used to anticipate supply chain challenges and to help to prevent food shortages by providing necessary insights that inform policy and mitigation responses.

The methodology of bringing satellite imagery into the damage analysis process increases the capacity to map unexploded ordnance across Ukraine's farmlands. The satellite imagery also provides an archive of Ukrainian agricultural lands, enabling the historical monitoring of any field in Ukraine; before, during, and after the conflict. This information is impossible to gather by any other means. This is why NASA Harvest is actively working on mapping craters and potential unexploded ordnance to prepare for assisting demining organisations in the future (NASA Harvest, 2023a). By incorporating this satellite-derived data, demining agencies are able to prioritise demining efforts in support of continued agricultural production, ultimately bolstering local food production and by extension global food security.

4 RESULTS

The agricultural sector in Ukraine is an important source of tax revenue for the government budget. According to the National Bank of Ukraine data, the share of agriculture in the GDP in 2021 was 10.2 percent, which was 1 percent higher than in 2020 (National Bank of Ukraine, 2022). Agriculture products account for the largest share of Ukraine's total exports, about 41 percent per year, and the livelihood of 13 million rural residents directly depends on the state of the national agricultural sector (Shulha, 2023). In 2022, Ukrainian farmers exported agro products for $20 billion, but these figures are 50 percent lower than the year before the full-scale Russian invasion in Ukraine. All this affects the world markets, because, to a large extent, due to the war in Ukraine, world food prices on average in 2022 were 14.3 percent higher than in 2021.

Tax revenues from the agro-industrial sector of the economy in 2021 amounted to almost UAH 50 billion, or 11 percent in the structure of all tax revenues. In addition, agriculture showed the highest increase in production in 2021, 14.4 percent, and by the end of 2021, production in the agricultural sector had grown by 19.2 percent. However, with the start of 2022, significant problems arose in the formation of budget revenues, as the full-scale war significantly weakened the financial capabilities of agribusinesses, especially, agricultural holdings which faced the problem of realizing their export potential due to the interruption of established logistics chains and the loss of significant material, technical and land resources in the areas of hostilities and in the front-line areas.

The experts of the Food and Agriculture Organization of the United Nations (FAO) calculated and estimated the actual losses from the damage to the assets of Ukrainian agricultural enterprises in 9 months of the war at 6.5 billion dollars (Ministry of Finance of Ukraine, 2021). As a result of the war, more than 10 thousand farmers lost the ability to work, which significantly changed the structure of the agricultural sector. As a result of the war, more than 10,000 farmers lost the ability to work, significantly reducing the fiscal revenue from the agriculture sector to budgets at all levels. Due to the decrease in the realization of agricultural products at the domestic market, a reduction in tax revenues for the three quarters of 2022 was 23.7 percent, compared to 2021 (Pepelia, 2022).

Tab. 1 shows the analysis of the quantitative and qualitative indicators of agricultural formations, based on their structure. The small commodity sector includes family and farmer households. Agricultural holdings and other types of entities are represented in the table as the corporate sector.

Over the past few years, the profitability level of farming has been competitive with the corporate sector, and in livestock and overall has exceeded the indicators of agribusinesses by 5–10 percent. In our opinion, it became the result of the implementation of affordable credit and government subsidies programs, as well as international grant support. However, the lack of modern multifunctional equipment and financial circulating assets in general is holding back the progressive farming movement.

After the declaration of martial law in Ukraine on 24th February 2022, agriculture, as the basis of food security and a component of national security, requires increased attention and all-around support from the government. Such support is being provided not only by Ukraine itself but also by many countries and international institutions. Tab. 2 provides an overview of the main challenges facing agriculture since the start of the war and the measures taken to address current problems.

With the beginning of a full-scale war, in order to preserve the traditional status of a world food exporter, Ukraine faced new security challenges in the use of maritime routes in the Black Sea. The grain agreement, which was concluded in Istanbul on 22nd July 2022 in order to protect merchant ships from Russian threats, with Turkey and the UN acting as guarantors, made it possible to create a "grain corridor" and temporarily unblock food exports

Tab. 1: Dynamics of individual quantitative and qualitative indicators of agricultural activity (based on State Statistics Service of Ukraine, 2021)

	Small commodity sector			Corporate sector			Percentage in the overall structure 2021	
Indicators	**2019**	**2020**	**2021**	**2019**	**2020**	**2021**	**Retail**	**Corporate**
Total farms (thousand)	45.6	46.9	46.7	10.8	10.9	10.7	81.4	18.6
Crop areas (thousand hectares)	3908.7	2981.1	2817.5	16334.7	16827.8	16526.5	14.6	85.4
Revenue from the sale of agricultural products (million euros)	1662.4	1684.8	1725.4	8285.8	8452.1	8525.1	16.9	83.1
Including crop production (million euros)	1363.1	1378.2	1381.3	6214.4	6358.6	6455.2	17.7	82.3
Including grain crops (million euros)	176.1	182.5	193.1	1895.1	1956.7	2019.1	8.8	91.2
Yield of grain crops (%)	44.0	37.4	38.5	53.7	46.4	48.2	*	*
Including animal husbandry (million euros)	299.3	306.6	344.1	2071.4	2093.5	2069.9	14.3	85.7
The level of profitability in crop production (%)	16.5	23.8	25.6	18.8	24.0	22.1	*	*
The level of profitability in animal husbandry (%)	30.1	28.3	28.1	18.1	18.0	18.1	*	*
Availability of agricultural machinery	88733	89205	89156	166343	165896	165754	34.9	65.1
Including combines	19986	20245	20165	44429	44513	44483	31.2	68.8
Tractors	41783	42563	42550	70746	71012	70982	37.5	62.5
Seed drills	18107	17510	17500	32538	33026	32984	34.7	65.3
Plant protection machines	8857	8887	8941	18630	17345	17305	34.1	65.9

from the ports "Odessa", "Chornomorsk" and "Pivdenny". Despite systematic sabotage by Russia to inspect ships and the risk of maritime corridor bypass, Ukraine was able to send 629 ships from 1st August 2022 to 8th January 2023, exporting 16.9 million tons of Ukrainian food to Asia, Europe, and Africa, making a significant contribution to the elimination of the global food crisis. In particular, 54 percent of the agri-food transported through the "grain corridor" reached the ports of European states, 28 percent to Asian countries, 12 percent to African countries, and 6 percent to countries in the Middle East.

To strengthen Ukraine's export positions, the official start of the Humanitarian Food Program "Grain from Ukraine" for the supply of grain to the most in need African countries, where there are already hunger problems, took place on 26th November 2022. The program foresees the dispatch of 60 ships with Ukrainian grain to mid-2023 to provide food for at least 5 million people. Under the Program, part of the export grain could be purchased by 30 participating countries and international organizations. Germany and Japan have already joined this program, paying for the freight of two ships. The United States Agency for International Development (USAID) has agreed to provide up to 20 million dollars for this initiative.

In order to ensure stable Ukrainian export, the process of effective implementation of the production potential of agricultural enterprises becomes important. Hostilities on the territory of Ukraine significantly complicate the production of agricultural products, prevent field work, and also cause significant financial losses to agricultural enterprises due to the loss of cultivated areas, the destruction of livestock and poultry farming, production buildings and structures, technical equipment, etc. Many livestock complexes and elevators were looted or

Tab. 2: The main challenges and measures taken regarding the development of agriculture in Ukraine during the war (data for January 2023)

No.	The main problems	Negative consequences	Implemented measures
1	Military blockade of the Black Sea (maritime roads)	Reduction of traditional export volumes in Ukraine	• Opening of the "grain corridor" and the elimination of the narrow fairway in the Black Sea waters • Humanitarian food program "Grain From Ukraine"
2	Losses of fixed assets (crop area, losses of livestock and poultry farming, buildings and structures, technical equipment)	Decrease in the productive capacity of agricultural production	• Adaptation of the "5-7-9" agribusiness lending program to the war situation • Substantial international financial support • Industry programs and measures for support and partial compensation for losses
3	Increase in the price of circulating assets (fuel, fertilizers)	Disruption in technology and terms of the agricultural works	• Temporary suspension of import excise tax on petroleum products and reduction of VAT • State monitoring of fuel prices • Ban on the export of mineral fertilizers
4	Shortage of circulating funds	Deficiency of seed material, protective measures, fuel	• Grants for farmers and family owned farms • Extension of agricultural lending programs • Financial support from FAO
5	Logistics chain disruptions	Stoppage or complicating functions of supply, production, and distribution of products	• Partial relocation of processing capacities
6	Mined fields	Phase out of farmlands due to danger of agricultural works	• EU provides financial support for programs aimed at demilitarizing territories
7	Migration and mobilization of industry workers	Shortage of workers in agribusiness	• Reserving workforce for agribusiness
8	Lack of electricity	Disruptions in technological cycles	• Cancelled VAT and customs duties on import of generators, transformators, batteries, etc. • International aid and preferential credits for alternative energy sources
9	Compensation for losses under insurance contracts	Force majeure circumstances of loss of plant and animal products	• Government support for insurance of agricultural products and recommendations for formation of evidence base for future loss compensation

blown up, and tractors, combines, agricultural machines and cars were stolen or destroyed. Moreover, these were fairly modern production complexes and technical equipment, which were actively updated in recent years.

NASA Harvest satellite analysis revealed a relatively high-yielding 2023 season for the Black Sea region for both wheat and sunflower, Ukraine's two main export crops. However, a significant part of this production was collected in the territories temporarily occupied by Russia, namely about 6.4 million tons of wheat and almost 1.5 million tons of sunflower seeds. All these products were stolen by Russia, as well as about 15–16 million tons of all agricultural crops produced in the occupied territories.

NASA Harvest, based on satellite analysis, estimates total wheat production in Ukraine in 2023 to be between 25 and 26.5 million tons, with between 21 and 22 million tons coming from the Ukraine-controlled territories and between 4.1 and 4.4 million tons coming from Russian-occupied territories (Fig. 1).

Yield is estimated to be higher than last season, at 4.27 ton/hectare for all of Ukraine (4.53 ton/hectare within Ukraine-controlled territories and 3.3 ton/hectare in Russian-occupied territories). On the other hand, planted area has decreased relative to last year, with between 5.8 and 6.2 million hectares planted across Ukraine (between 4.6 and 4.9 million hectares on Ukraine-controlled areas, and between 1.2

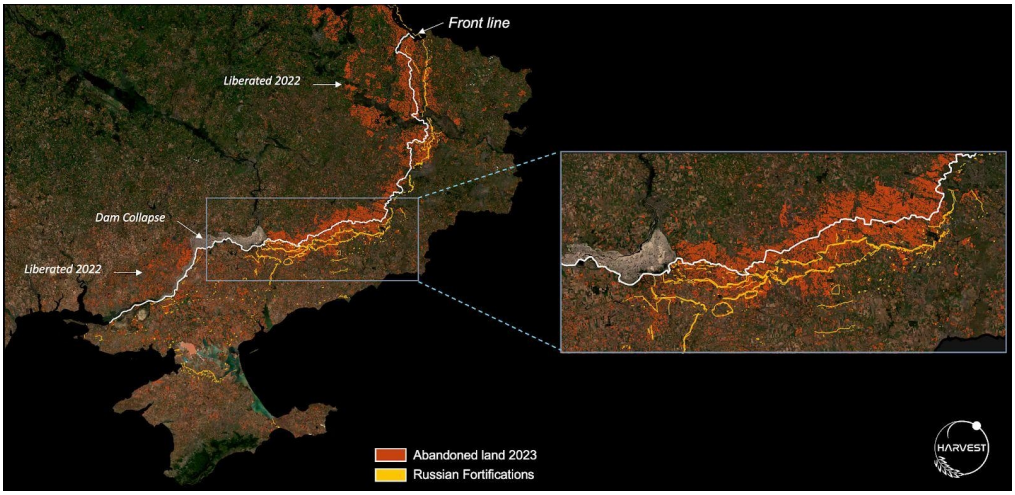

Fig. 1: Derelict Farmland Along the Front Line and NASA Harvest Satellite Estimates for July 2023 (Satellite Data Source: PlanetScope, Russian fortifications source: Brady Africk)

and 1.3 million hectares planted on the Russian-occupied territories).

Overall, this year's wheat production estimate is close to last year's estimate – driven by lower planted area and higher yields relative to last year – but it is slightly below the 5 year average (prior to the war) of 27.9 million tons. It is important to admit that this assume that all planted wheat will be harvested, and that satellites cannot provide information on who would harvest the wheat and whether Ukraine will see the economic benefits of its fertile farmlands (NASA Harvest, 2023b).

Damaged fields, loss of irrigation infrastructure, the dangers of planting in a warzone, and the long term impacts of abandoned farmlands are also gradually coming to light. NASA Harvest preliminary analysis estimates that between 5.2 and 6.9 million acres (2.1–2.8 million hectares) of farmland have been abandoned as a result of the war since its beginning. These abandoned fields represent between 6.5 and 8.5 percent of Ukraine's total cropland and unsurprisingly lie along the war's front lines. Additionally, NASA Harvest estimates that just this year alone Ukraine has seen around $2 billion in economic losses due to lost harvest on the now-fallow fields and that these lost crops could have fed upwards of 25 million people for an entire year (NASA Harvest, 2023a).

In order to neutralise the catastrophic consequences for the national economy in Ukraine, alongside the adaptation of existing credit programs, other stabilisation measures were taken to support agricultural production.

The "5-7-9" program was launched in February 2020 which allowed small businesses to obtain preferential loans with interest rates ranging from 5 to 9 percent and a maximum loan amount of 50 million hryvnias. As of the beginning of the program, businesses have received a total of 161.86 billion hryvnias, 72.24 billion of which was received during the war period. This is the main preferential lending program in Ukraine.

Since the start of full-scale war, the government promptly responded to the urgent need of farmers for preferential lending and the program was expanded to include agricultural businesses with the possibility of obtaining loans at 0 percent interest (with rates ranging from 0 to 9 percent). The loan amount for agricultural enterprises ranges from 100 thousand to 90 million hryvnias and the state has provided 80 percent guarantees for this loan and allowed grain to be included as collateral. Within this program, farmers have received about 40 billion hryvnias, and some banks have launched targeted loan programs at 0 percent interest within the framework of "5-7-9" for

the purchase of generators, Starlinks, and other equipment.

In general, in 2022, farmers received loans for a total amount of more than UAH 90 billion, and the EU provided 50 million euros in the form of subsidies and grants for the cultivation from 1 to 120 hectares of agricultural land per year and for the keeping from 3 to 100 cows. Until 5th June 2023, the import duties on Ukrainian goods to the countries of the European Union are cancelled. The decision of the European Parliament under No. 2022/870 states that all tariff quotas for agricultural products and anti-dumping duties on imports of goods originating from Ukraine are suspended. In addition, the European Union has a transport visa-free regime for Ukraine.

Considerable international financial support for Ukraine is provided by USAID, in particular, agronomic support for three thousand agricultural producers who were particularly affected by the war is provided for a total amount of 35 million USD. Also, credit unions of Ukraine, which are USAID partners, within the framework of the "Credit resources for agricultural producers" project, will provide small agricultural producers with loans in the amount of 8.9 million USD.

Considering the main resources losses since the beginning of the full-scale war, the state support for the Ukrainian agricultural sector, in addition to credit programs, included:

- simplification of the procedure for obtaining land plots (leases) for their cultivation;
- partial reimbursement of the cost of purchased breeding animals for further reproduction;
- partial reimbursement of the cost of constructing and/or reconstructing livestock farms, processing agricultural products and grain storage enterprises;
- financial support for the development of horticulture, viticulture and hops, subsidies for beekeeping, grants for the creation of greenhouses;
- financial support for the farms development;
- exemption from import duty taxation of products and equipment for storage, transportation, loading and unloading of grain and/or oil crops (polymer sleeves for grain storage (Kolodiichuk and Dubnevych, 2019), trailers and semi-trailers for transportation of agricultural products);
- simplified procedure for registering agricultural machinery and state inspection of its technical condition.
- reduced VAT on fuel and lubricating materials, etc.

Average fuel prices rose even before the start of a full-scale war, which was explained by high oil prices on world exchanges and the decline in the hryvnia exchange rate. Only since the beginning of 2022, the prices of gasoline and diesel fuel in Ukraine have increased by 14–15 percent. After the start of hostilities, the purchase of Belarusian fuel was stopped, the sea channels for the oil and petroleum products supply were lost, and control over oil refining facilities in the east of Ukraine was lost as well. Significant volumes were also needed for the front, and all this caused shortages and restrictions on the supply of fuel, speculation and an uncontrolled rise in prices. Against the background of panic, with the aim of stimulating imports and restraining domestic prices, the state intervened in the regulation of the fuel market by cancelling the excise tax on imports and reducing VAT. These measures had a positive effect on providing agricultural producers with fuel during spring field work. In order to prevent artificial price increases and speculation, the State Consumer Service of Ukraine conducts daily price control of 26 items of basic socially significant goods, including fuel prices.

The shortage and significant increase in the cost of fertilizers has made agriculture in Ukraine much more difficult, as most of the facilities for their production have already been stopped, as a large part of them are located nearby or directly in the war zones. For example, the "Sumykhimprom" plant suffered from shelling and it caused the ammonia leakage. The "Azot" chemical plant in Severodonetsk (15.3 percent of Ukraine's nitrogen fertilizer production) is situated in an area beyond Ukrainian government control and doesn't work. The Odessa Port Chemical Plant

(14.4 percent of Ukraine's nitrogen fertilizer capacity) has been shut down since the conflict began, and "Rivneazot" is situated in a potentially hazardous zone where rocket attacks are possible. Even on remote fertilizer production plants, there is a significant threat to the lives of employees and residents of nearby communities, as the enemy conducts shelling with missiles and drones, while workers have to work with the explosive and poisonous materials.

Starting from 12nd March 2022, Ukraine has implemented a ban on the export of fertilizers to preserve the market balance during the ongoing war. In 2021, almost 45 percent of Ukrainian exports of nitrogen fertilizers were accounted for by the EU. The largest importers of Ukrainian nitrogen fertilizers (SuperAgronom.com, 2023) were Romania (190,000 tons), Italy (138,000 tons), France (104,000 tons), Hungary (88,000 tons), Spain (56,000 tons), Bulgaria (50,000 tons), and Poland (40,000 tons). Under current circumstances, EU countries will need to search for alternative sources of nitrogen fertilizer supply. Meanwhile, the production of complex fertilizers is not sufficiently developed in Ukraine. In 2021, 1.9 million tons of them were imported. The largest source was Belarus (617 thousand tons), which was 32.1 percent of the total volume (SuperAgronom.com, 2023) and after breaking economic relations with it, Ukraine needs to find alternative sources of imports.

In general, the issue of disruption of logistics chains (Kolodiichuk et al., 2020) became extremely acute with the beginning of full-scale hostilities. The loss of enterprise resources and the destruction of the transport infrastructure made it impossible to use traditional channels of supply and distribution of products, and in many cases paralyzed the production and marketing activities of agricultural enterprises. A partial solution of this issue was achieved due to the relocation of enterprises to the rear regions of Ukraine, but this is impossible for agricultural production.

In order to conduct the effective agricultural production, farmers need working capital to purchase seed material, plant protection products, equipment repairs, and so on. In the first quarter of 2023, a shortage of working capital will be a limiting factor in the development of agricultural production, and for this reason the state has extended the state program "Affordable loans '5-7-9" to provide targeted support for agricultural producers.

An unexpected challenge for the Ukrainian agricultural sector in 2022 was the issue of mining fields and dirt roads in the de-occupied territories, which posed significant risks to the life and health of machine operators. Funding of the programs for demining the territory has been a question for a decade not only for Ukraine, but also for international donors. According to estimates of the Ukrainian Association of Sappers (`https://www.uda.org.ua/`), in particular, by the beginning of 2023, about 139,000 square meters. km contaminated with various types of explosive objects.

According to the commander-in-chief of the Armed Forces of Ukraine Valery Zaluzhny (`https://cutt.ly/PwFod51o`), in August 2022, the Russians fired 40–60 thousand shells at Ukrainian positions every day (Fig. 2). According to various estimates, up to 20 percent of the fired ammunition does not explode. In addition, if the Russians stay in a certain area for a long time, they place mines in forests and fields. According to the assessment of the Ukrainian Club of Agrarian Business (`https://www.ucab.ua/en/`), about 2 million hectares of fields have been mined in the liberated regions. Each year of idleness of these lands will cost the country's economy up to 800 million USD. There are 6 million hectares under temporary occupation, which will also require inspection after liberation (Miroshnychenko, 2023).

The shortage of skilled labor in the agricultural sector has been felt for some time, and the introduction of a state of emergency in Ukraine due to the Russian-Ukrainian war, and with it, a general mobilization, has led to an even greater shortage of industry professionals, including drivers, tractor operators, agronomists, and zoo technicians. Additionally, Russia's full-scale armed aggression against Ukraine has caused one of the most rapid crises of forced displacement of people both within the country and abroad. Since the agrarian rear is no less

Fig. 2: The state of the fields near the village of Dovhenke in Kharkiv Oblast (satellite images by Maxar Technologies)

important for the state defence, and holding the 2022 sowing year is one of the strategic goals, under such conditions the government included employees of agricultural enterprises in the list of professions that can receive a postponement from mobilization.

Massive rocket attacks on Ukraine's energy infrastructure facilities, which Russia systematically makes, have a significant negative impact on the agricultural sector and have resulted in a considerable deficit of capacity in Ukraine's energy system. Under these conditions, the risks of halting technological processes in agriculture are significantly increasing, and in some sectors, such as animal husbandry or poultry farming (incubators, etc.), these risks become critical. The absence of electricity is particularly noticeable in horticulture, during post-harvest crop treatment (drying, sorting), and so on. To solve these issues partially, Ukraine has abolished VAT and import duties on generators, transformers, batteries, and other similar equipment. According to Ukrinform (Ukrinform, 2023), the World Bank will provide USD 50 million in 2023 to ensure that Ukrainian elevators are equipped with generators or boilers, allowing each elevator to partially offset the purchase of new generators, up to a sum of 5 million UAH or switch to LPG.

Despite the fact that agricultural insurance is an important tool for effective agrarian policy, only slightly more than 5 percent of agricultural lands in Ukraine are insured, while in the United States, this figure reaches 90 percent. Generally, farmers had to prioritize insurance of agricultural equipment since it is a condition for purchasing it on credit or leasing schemes, while there is often not enough funding for crop and livestock insurance. This is also due to the reluctance of insurance companies to take on potentially high risks. This fact significantly increases the cost of insurance products. In view of global climate changes and growing risks of loss of products important for national security, it is obvious that the process of agricultural insurance requires state support as well. In Ukraine, an important law "On the features of insurance of agricultural products with state support" was adopted on 24th July 2021, as well as the Resolution of the Cabinet of Ministers "On approval of the procedure for providing state support for insurance of agricultural products" dated on 12th February 2022. State support for the insurance of agricultural products involves compensation from the state budget up to 60 percent of the insurance payment.

However, with the beginning of a full-scale war, which caused the temporary occupation by Russia a significant agricultural territory, the prevention of agricultural work due to shelling of fields, their mining, fires, etc., significant problems arose with insurance compensation for losses of agricultural products. If the insured event occurred during the period of martial law and the insurance contract provides for it, the insurance company is not released from its obligations to the client. Since, as a rule, damage caused as a result of hostilities is not determined by an insured event, the institution of force majeure may be applied accordingly, which means depriving the business entity of compensation for losses. Therefore, the main task for agricultural producers, at the moment, is to record and document (if possible) all the facts of losses of products and material assets, as an evidence base for compensation of losses in the post-war period.

5 DISCUSSION

The model for post-war agricultural structure in Ukraine is envisioned as a balanced development of corporate and smallholder sectors, with a shift in priorities towards the development of small peasant and farmer households, as the foundation for ensuring the stability of the national food system, ecological safety, and rural development in the context of the administrative reform in Ukraine. The farmer structure with strong peasant family farms is more socially oriented, contributes to employment, and provides high-quality food using local resources. While large agricultural holdings, with alternative sources of financing, often having foreign beneficiaries, or powerful lobbyists in government structures, are self-sufficient, however the development of small agriculture enterprises requires strong government support.

For the successful development of farming in Ukraine, it is necessary to develop an appropriate National Plan with a non-declarative nature, but with clear spatial and temporal criteria for the relevant implementation. This plan should be an integral part of the reconstruction plan of Ukraine with appropriate guarantees of financing, implementation and control (Fig. 3).

For the successful implementation of the perspective plan, an appropriate conceptual-legal and organizational-institutional basis should be created, with further functional support for the implementation of its stages.

The conceptual-legal basis (see Fig. 3) will include the national and international context, which requires legislative guarantees and compliance with international guidelines. We believe that it is primarily necessary to establish farming as the basis of the national agrarian system by making appropriate changes to the Constitution of Ukraine, which will officially define farming as the basis for the formation of a powerful middle class in the countryside. In Poland, for example, the priority of family farming is enshrined at the constitutional level: Article 23 of the Constitution of Poland defines that "… the basis of the agricultural system of the state is family farming" (Bilousova, 2021). The status of agricultural entities should be defined in the Budget Code, and other legislative changes should be made to guarantee them systematic state financial support.

The National Action Plan for the Development of Farming should be adapted to the Common Agricultural Policy (CAP) of the European Union, which is especially relevant in the context of Ukraine's European integration aspirations. At the same time, it is necessary to ratify and take into account the provisions of the UN Declaration "On the Rights of Peasants and Other People Working in Rural Areas" (UNDROP). Also, one of the significant contemporary trends and guidelines for the development of agriculture and rural areas in Ukraine should be the UN Decade of Family Farming (2019–2028), which will significantly facilitate the attraction of international finance for sectoral reform, as well as promote the development and consultative support for the farming movements in Ukraine.

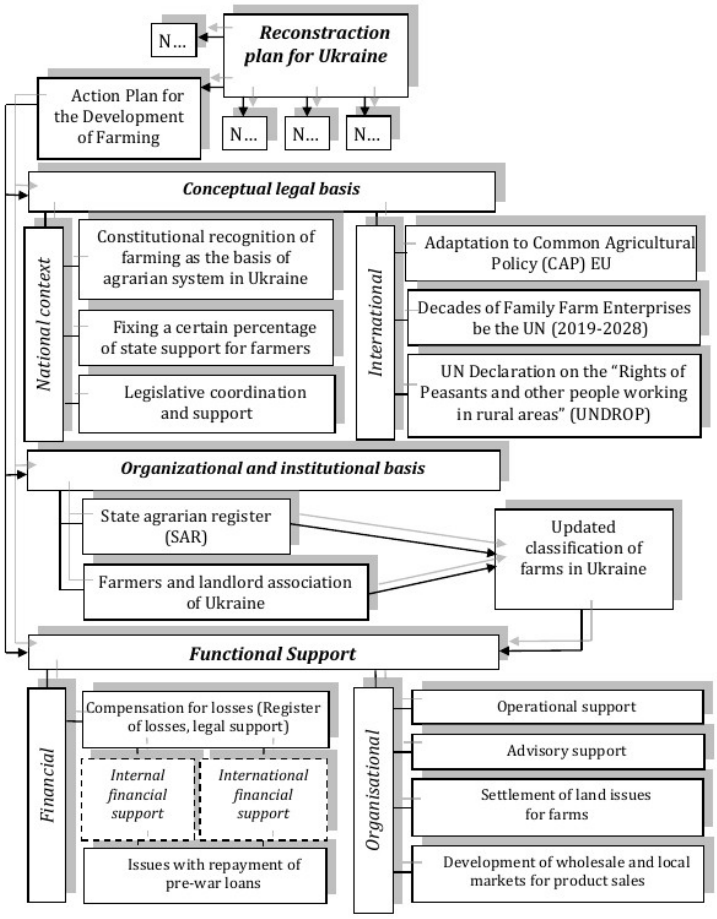

Fig. 3: Preconditions for the development of the National Action Plan for the Development of Farming

The organizational and institutional basis for the development of the national farming development plan (see Fig. 3) should provide conditions for the structural-functional realization of its stages. For this aim the State Agrarian Register (State Agrarian Register, 2022) already operates in Ukraine, which is an automated electronic system created by the Ministry of Agrarian Policy for the effective and transparent mobilization and allocation of all types of support for Ukrainian agrarians, both from the state budget and in the form of preferential loans, international grants, or technical assistance. The Association of Farmers and Private Landowners of Ukraine should play an important role in ensuring effective control over the distribution of financial resources and targeted support for agricultural entities, as the most professional and competent structure in the industry's problems, which is organizationally represented in all regions of the state.

In Ukraine, there is no clear classification of farms, and this complicates the process of state support for the development of farming, because the cultivated areas of different farmers can differ hundreds of times. In our opinion, it is necessary to classify farms clearly based on the criteria of scale of activity and their specialization with the introduction of appropriate changes to the laws of Ukraine "About farming" (Verkhovna Rada of Ukraine, 2003), "About amendments to some laws of Ukraine regarding the functioning of the State Agrarian Register and improvement of state support producers of agricultural products" (Verkhovna Rada of Ukraine, 2020).

The goal of the Plan is to implement practical stages for the development of farming, which should be based on the principles of predictability and long-term planning. To achieve this, it is necessary to introduce longer planning periods for the development of the agricultural sector – by analogy with the five-year budget planning within the EU's Common Agricultural Policy (CAP).

Functional support for the National Action Plan for the Development of Farming (see Fig. 3) includes financial and organizational components, which should ensure the implementation of reforms at the empirical level. Along with compensation for direct losses due to hostilities, it is necessary to address the issue of the return of loans taken out by farmers before the war to purchase equipment, planting material, etc., which were destroyed or stolen (including the harvest) in the zone of hostilities. The Plan should also clearly define the structure of internal and international sources of funding.

In order to ensure the effective implementation of the agricultural reform in Ukraine, operational support, which involves the coordination and start of the implementation of relevant strategies and action plans in the field of reform, becomes important. This is preceded by the legislative regulation of land issues in the agrarian sector of the economy and the provisions of legislation on the market circulation of land.

For the successful implementation of the National Action Plan for the Development of Farming, the advisory institute, the development of wholesale and local markets for the sale of products, logistics infrastructure (Kolodiichuk et al., 2023), outsourcing (Kolodiichuk et al., 2021), etc., are of great importance. Most of such projects should, in our opinion, be implemented within the framework of public-private partnership.

6 CONCLUSIONS

Thus, farming is the weakest link of the national agrarian structure, as a result of inadequate state support and unfair competition from agricultural holdings. However, with the start of full-scale war, farmers and individual peasant farms have demonstrated the highest adaptability in preserving and developing local food markets and supply chains and have become a reliable source of food for the population. Nevertheless, almost all agricultural producers of Ukraine were affected by the hostilities, which faced unprecedented challenges, among which we highlight: military blockade by the aggressor of sea routes for the traditional export of grain crops; catastrophic losses of capital assets due to their destruction and theft; disruption of traditional logistics chains of sales of products and supply of working capital, which, against the background of the decline of the national economy, caused their shortage and significant increase in prices and significantly limited the access of business entities to their purchase due to the lack of working capital. The mining of fields in the de-occupied territories and in the war zone significantly increases the risks of conducting field work, and the forced migration and mobilization of workers in the industry causes a shortage of labor resources, which, against the background of forced power outages and the destruction of infrastructure, inhibits their effective use.

Quantifiable and timely information received from satellite data regarding the amount of food produced by both free-Ukraine and Russian-occupied Ukraine provides us with critical tools needed for making balanced policy and trade decisions, for adapting to changes, and for managing resources more effectively. While the war continues, NASA Harvest continues using Earth observations to shed light on the state of agriculture throughout the Black Sea region. Understanding changes in planted area, types of crops being produced, crop yields, damaged lands, and changes in farming practices due to the war are very helpful to inform policy makers locally, and ultimately help to stabilize food supply and reduce market volatility on the global level.

We see the model of the post-war structure of Ukraine's agriculture in the balanced development of the corporate and small commodity sectors with a shift in priorities to the development of small peasant and farm holdings. For this, it is necessary to develop a National Action Plan for the Development of Farming, which should be an integral part of the post-war reconstruction plan of Ukraine, with appropriate guarantees of funding, implementation and control. For the successful implementation of the long-term plan, it is necessary to create an appropriate conceptual-legal and organizational-institutional basis with further financial and organizational support for the implementation of its stages. Compensation for losses caused by the war and changes in the state's agrarian system in the direction of supporting the development of farming will contribute to the stability of the national food system, environmental security and socially oriented development of rural areas in the context of land and administrative reform in Ukraine.

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AUTHOR'S ADDRESS

Volodymyr Anatoliiovych Kolodiichuk, Department of Management, Stepan Gzhytskyi National University of Veterinary Medicine and Biotechnologies, 50 Pekarska Street, Lviv, 79010, Ukraine, e-mail: V-A-K@ukr.net (corresponding author)

Ivan Mykolaiovych Tofan, Lviv National Environmental University, 1 V. Velykoho Str., Dubliany, Lviv region, 80381, Ukraine, e-mail: imt71@ukr.net

Iryna Anatoliivna Kolodiichuk, Dolishniy Institute of Regional Research of NAS of Ukraine, 4 Kozelnitska Street, Lviv, 79026, Ukraine, e-mail: ira1166@ukr.net

Igor Volodymyrovych Voronyj, Stepan Gzhytskyi National University of Veterinary Medicine and Biotechnologies, 50 Pekarska Street, Lviv, 79010, Ukraine, e-mail: romvoronyj@bigmir.net

INDIRECT COST IN SHOULD COST CALCULATIONS – HOW CARMAKER'S COST ENGINEERS SEE IT

Remo Rossi[1], David Hampel[1]✉

[1] *Mendel University in Brno, Czech Republic*

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ABSTRACT

In a world of intense competition, automotive manufacturers are continually increasing their outsourcing activities and, as a result, automotive companies have built extensive cost engineering departments within their organisations. Staff in these units provide Should Cost Calculations for externally manufactured components, which are utilized as supplier targets to support buyers in fact-based negotiations. This paper aims to explore potential differences in the direct and indirect cost categories in the context of Should Cost Calculations. Based on a sample survey among cost engineers, it was possible to determine differences in cost knowledge, risk of suppliers concealing unjustified costs, level of analytical detail, and suitability to conduct fact-based negotiations depending on the length of job experience, industry, and especially the type of costs. The evaluation is carried out through analysis of variance, and a contingency table homogeneity test, and the results are presented using correspondence maps. The results show significant differences between the direct and indirect cost categories, including a higher risk of cost hiding and a lower suitability for price negotiations for the indirect cost category.

KEY WORDS

analysis of variance, automotive industry, correspondence analysis, cost engineering, direct cost, indirect cost, questionnaire survey, Should Cost Calculation

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1 INTRODUCTION

In a world of growing global competition, carmakers increased their outsourcing activities within the last decades. Today externally sourced components contribute between 50–70% to the total cost structure of a car (Large, 2009) while carmakers' annual purchase volumes have climbed up to hundreds of billion USD (Gramatins and Zabota, 2007; Mayer and

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Volk, 2017). One consequence of this development is the need for highly coordinated supply chains that help increase carmaker productivity (Douglas and Griffin, 1996). Even by realizing small cost improvements on a purchased component car manufacturers can realize huge lifetime savings (Batson, 2011). For that reason, automakers have built up cost engineering organizations. A crucial task of these divisions is to provide Should Cost Calculations (SCCs) before supplier nomination to set challenging sourcing targets and to support purchasing in fact-based negotiations. Although cost reduction is the ultimate goal here as well, this paper is not focussing on direct cost modelling and cost optimisation as it is described in academic literature e.g. Bolfek (2021).

Few researchers have described in detail the process of how carmaker cost engineers create these analytic bottom-up calculations and what type of information requirements are needed to generate them (Roy et al., 2011). These authors focussed primarily on the direct cost categories in SCCs. Hence it remains unclear if and on what level of analytic detail indirect cost categories are currently considered in SCCs. This is surprising since the impact of modern manufacturing processes on indirect activities and indirect cost has been recognized and deeply discussed by economic researchers in the field of cost accounting already in the 80s of last century (Cooper and Kaplan, 1988a; Cooper and Kaplan, 1988b).

Study Hoffjan and Lührs (2010), which involved key account managers of automotive suppliers confirmed in expert interviews that automotive suppliers provide biased and manipulated cost breakdown information to protect their profit margins. Authors state that there is a higher chance to generate additional profits by not communicating profits transparently to their customers but by including them in the overheads of to-be-delivered cost breakdowns (Hoffjan and Lührs, 2010). This indicates a certain "black box character" and a potential weakness in carmakers SCC. Tah et al. (1994) provide survey points to the fact that methods of indirect cost estimation used in practice are highly subjective; statistical methods are used rarely in this field. Deevski (2019) focuses on indirect cost determination methods generally. A survey addressed to companies of different sizes and industries on cost allocation methods used in company practice is provided there. The management of indirect costs is identified in the paper as one of the most complex areas to manage. Among their results, Farooq and Jibran (2018) note that studies dealing with indirect costs are a literature gap, particularly in developing countries, and further research is desirable to address the determinants of indirect costs.

The aim of this paper is to identify potential differences in the perception of direct and indirect costs by cost engineers engaged in SCC. This objective is decomposed into the following research questions:

- RQ_1: Is the carmaker's cost engineers' cost knowledge in indirect cost categories lower compared to the direct cost categories?
- RQ_2: Do carmaker's cost engineers perceive a higher risk, that not justified cost or profits are potentially hidden within the indirect cost categories?
- RQ_3: Do car manufacturers' cost engineers perform their SCCs within different levels of analytic detail within direct and indirect cost categories?
- RQ_4: How do carmaker's cost engineers rate the suitability to conduct fact-based negotiations within direct and indirect cost categories of their SCC?

Why are these questions important? The cost engineer's cost knowledge includes two dimensions. The first dimension is based on the individual knowledge of a cost engineer concerning type, size, and relationship among different cost elements, that have a crucial impact on a specific cost type or category. The second dimension refers to cost knowledge management (e.g. specific cost libraries or databases) in cost engineering departments, that enables cost engineers to access reliable and accurate input factors and cost rates for Should Costing. Analytic detail refers to a formal and transparent calculation of cost in a cost category based on multiple cost elements and variables. Analytic detail is not given in

case costs are rather determined based on rules of thumb instead of applying an analytic and repeatable arithmetic methodology. Finally, the suitability to conduct fact-based negotiations refers to the possibility of discussing identified cost gaps between Should Cost Calculation and the supplier's price breakdown in a detailed and transparent manner.

2 MATERIAL

In order to collect individual responses from a global population of cost engineers an electronic survey was created to place it within an appropriate internet channel, to ensure a convenient and efficient process of data collection and analysis. The data was collected within the timeframe May–July 2022. Theoretically, approximately 6000 cost engineers were contacted (see below), of whom 128 completed the questionnaire.

The survey was placed within a channel on LinkedIn, which is administered by the "Society of Product Cost Engineering and Analytics" (SPCEA) in which more than 6000 cost engineering professionals perform networking and share information dedicated to the field of cost engineering (SPCEA, 2022a). The SPCEA is a non-profit organization which is focusing on knowledge sharing, education, networking, and the establishment of standards within the field of cost engineering. This includes promotion and understanding of cost engineering principles and methods (SPCEA, 2022b). Due to the reason of huge number of active cost engineering experts – especially with automotive and aerospace backgrounds – the platform is frequently used by researchers to place surveys that are dedicated to the field of cost engineering.

In the automotive industry, direct and indirect costs can be distinguished as follows. Direct costs include Raw material costs (D_1), which include costs for raw materials (e.g. specific type of resin). Material costs are a direct cost category since they can be directly traced to the calculated product based on the to be considered weight. Direct labour costs (D_2) include the cost of direct labour activities (e.g. assemblers, machine operators). Based on different qualification levels for different operations they are directly traced to the calculated product. The cost allocation to the calculated product is performed by considering fully fringed hourly rates, headcount and required process cycle times of the required manufacturing processes. Finally, Machine costs (D_3) include costs of depreciation, financing, machine capital, cost for energy, consumables, spare parts, and maintenance. The reason for considering machine costs within the direct cost categories is based on the cost engineering practice to trace machine costs in a direct and activity-based manner to the calculated product. Annual machine budgets are aggregated in individual machine cost centres within the first steps. Afterward, single-machine hourly rates can be determined by dividing the total annual cost of single-machine cost centres by total productive machine hours. That way machine cost can be traced in a direct and activity-based manner to the calculated product based on the manufacturing cycle times of to be considered manufacturing processes.

Among indirect costs, two categories will be considered: Material- and Manufacturing overheads. Material overheads (I_1) include overheads on raw materials and purchased components. This includes the cost of warehouses, that are required to store incoming goods. The cost to pay salaries for indirect labour, which performs activities in material ordering, planning, inspection, and storage is also considered in this cost category. The second category of indirect costs is Manufacturing overheads (I_2) which includes all residual overheads of manufacturing within a factory, which are not covered in the machine hourly rates. This includes exemplarily salaries of plant management and indirect labour, which is not covered in the material overheads. Another typical example, that falls into this cost category is the costs of the finished goods warehouse or shared facilities.

The survey structure contained a total of 6 major questions. The initial two questions were used to determine the work experience of cost engineers and in which industries they are employed. The remaining 4 questions rate:

- Y_1 – cost engineer's cost knowledge within the different cost categories,
- Y_2 – perceived risk that suppliers hide successfully not acceptable costs in a cost category,
- Y_3 – level of analytical detail that is applied in the cost category,
- Y_4 – suitability to conduct fact-based negotiations within the cost categories,

where the participants had to provide their Likert Scale ratings with values between 1–5 for direct cost categories D_1, D_2, and D_3 and indirect cost categories I_1 and I_2 defined in the previous section.

For each respondent and all Y_i, the direct cost score is determined as the average of the values for D_1 to D_3 and the indirect cost score as the average of the values for I_1 and I_2. For the initial factor analysis of variance, a "Cost type" factor was constructed with "Direct" and "Indirect" levels, based on cost score type. In this manner, data for a three-way analysis of variance were prepared consisting of factors Cost type, Industry (with levels Aerospace, Automotive-carmaker, Automotive-supplier, Other), and Experience (with levels Three and less years of praxis; More than three years of praxis).

Based on the results of the factor analysis of variance, a more homogenous group of respondents was selected, consisting of 47 respondents. Only these responses were finally taken into consideration for further analysis in case participants were marked to be employed by a carmaker. Whenever participants indicated to work for an automotive supplier or in another industry their responses were not considered within the final analysis. In addition to that responses were excluded, whenever participants declared to have three or less years of job experience within the field of cost engineering. Within this sample, two respondents were excluded due to distortions in response quality (they answered all questions with the same level of response), resulting in the final sample of 45 respondents for analysis in the contingency table.

3 METHODS

Three-way analysis of variance was performed in the form of a general linear model. Schematically, we can write

$$\text{Score}_{ijk} = \text{Cost type}_i + \text{Experience}_j + \\ + \text{Industry}_k + e_{ijk},$$

where e stays for error term, $i = 1, 2$, $j = 1, 2$ and $k = 1, \ldots, 4$. Since the score is an average of only a few values, the normality assumed for this analysis is only approximate. After the determination of the significance of the factor, post-hoc analysis was employed using the least significant difference approach. For the reduced dataset we tested the following hypotheses:

- H_1: Cost engineers rate their cost knowledge higher in indirect cost categories compared to the direct cost categories of their SCC.
- H_2: Cost engineers rate the risk that a supplier is successfully hiding not acceptable cost or profit higher within indirect cost categories compared to the direct cost categories of their SCC.
- H_3: Cost engineers rate the level of analytic detail lower in indirect cost categories of their SCC compared to direct cost categories.
- H_4: Cost engineers rate the suitability to conduct fact-based negotiations lower in indirect cost categories compared to direct cost categories of their SCC.

For this purpose, we employed the test for homogeneity in a contingency table. For this test we assume fixed row counts (in rows different cost types are placed). Technically, we test whether the multinomial distributions

in the rows of the contingency table are identical or not. The null hypothesis is that the multinomial distributions are the same; the alternative is that they are not, which can be represented by our hypotheses H_1 to H_4. Testing statistics is the same as for χ^2-test of independence in the contingency table (Walliman, 2018). This test assumes theoretical frequencies greater than 5 in 80% of cases and greater than 2 in the remaining 20% of cases. If the null hypothesis is rejected, it is necessary to find out where the homogeneity violation lies. For this purpose, we have used correspondence analysis, the outputs of which will allow us to describe the relationship between the row and column variables of the contingency table using the so-called biplot (Greenacre, 2007). Specifically, we used a symmetric model applied according to Lorenzo-Seva et al. (2009).

Statistical testing was performed on a significance level of 0.05. The general linear model was estimated in the software Genstat 23, and data manipulation, homogeneity tests in a contingency table, and correspondence analysis were performed in the computational system Matlab R2023b.

4 RESULTS

A description of the surveyed dataset is given in Tab. 1. Cost engineers from the Automotive-carmaker industry with longer experience predominate (38.5%). Less experienced experts make up about a quarter of the respondents. Of note is the low proportion of cost engineers with shorter experience in the Automotive-carmakers industry compared to other industries. This may mean that cost engineers find employment in the Automotive-carmakers industry only with more experience in the same position in another industry, as the job of a cost engineer in the Automotive-carmakers industry is considerably more demanding.

Tab. 1: Composition of original dataset presented by contingency table, in %

Experience	Auto-carmaker	Auto-supplier	Aero space	Other	Total
Three years and less	3	7	6	8	24
More than three years	39	15	7	15	76
Total	42	22	13	23	100

Three-way analysis of variance is applied to data for variables $Y_1, \ldots, Y_4$ gradually. All three factors are statistically significant when assessing cost engineer's cost knowledge within the different cost categories, see Tab. 2. Automotive-carmaker industry with a predicted score of 2.87 is not statistically different from the Aerospace industry (2.72) and these industries significantly differ from the Automotive-supplier and Other industries with scores 3.37 and 3.12. Significantly lower scores for Automotive-carmaker and Aerospace industries are given by more complex production based on many components. Cost engineers with three and less years of experience evaluate themselves by a significantly lower predicted score (2.65) than cost engineers with longer practice (score of 3.14). This result indicates a healthy self-criticism of less experienced cost engineers and suggests the credibility of the questionnaire survey. The predicted score for indirect cost knowledge 2.21 is significantly lower than the score for direct cost knowledge (3.83) of cost engineers. This preliminary result is consistent with our hypotheses.

Tab. 2: ANOVA table for Y_1 – cost engineer's cost knowledge within the different cost categories

Factor	d.f.	s.s.	m.s.	F	p
Industry	3	10.63	3.54	3.81	0.011
Experience	1	9.77	9.77	10.52	0.001
Cost type	1	160.40	160.40	172.64	< 0.001
Residual	238	221.13	0.93		
Total	243	401.93	1.65		

Statistically significant differences between predicted scores of indirect and direct costs are detected in all cases, see Tab. 3: the risk that a supplier is successfully hiding not acceptable

cost has a predicted score of 4.89 for indirect cost vs. 2.96 for direct cost; score of analytic detail for indirect cost 2.13 is significantly lower than the score for direct cost 3.81; score of suitability to conduct fact-based negotiations for indirect cost 2.01 is significantly lower than score for direct cost 3.74. For different industries were statistically significant differences detected between the Aerospace industry (2.67) and other industries (Automotive-carmaker 3.00, Automotive-supplier 3.18, and Other 2.92) in the case of analytic detail level. Suitability to conduct fact-based negotiations is significantly lower in the Aerospace industry (2.46) than in the Automotive-carmaker (2.82) and Other (2.87), and these industries have significantly lower scores than the Automotive-supplier industry with a predicted score of 3.21. Note that a complete overview of predicted scores is present in Tab. 4.

Tab. 3: Statistical significance of factors related to variables $Y_1, \ldots, Y_4$ expressed by p-values

Factor	Y_1	Y_2	Y_3	Y_4
Industry	0.011	0.744	0.036	0.003
Experience	0.001	0.489	0.215	0.278
Cost type	< 0.001	< 0.001	< 0.001	< 0.001

Tab. 4: Predicted scores for all factors related to variables $Y_1, \ldots, Y_4$

Factor	**Factor levels**	Y_1	Y_2	Y_3	Y_4
Industry	Aerospace	2.73	3.57	2.67	2.46
	Automotive-carmaker	2.87	3.74	3.00	2.82
	Automotive-supplier	3.37	3.62	3.18	3.21
	Other	3.13	3.66	2.92	2.87
Experience	More than three years	3.14	3.65	3.02	2.91
	Three years and less	2.65	3.73	2.85	2.75
CostType	Direct costs	3.83	2.96	3.83	3.74
	Indirect costs	2.21	4.39	2.13	2.01

Overall, the results of the analysis of variance indicate a different assessment of direct and indirect costs across all questions examined. In addition, cost engineers with shorter experience self-critically rate their knowledge as not as extensive as their colleagues with longer experience. Since it usually takes three years to have full job experience and knowledge to provide independent Should Cost Calculations, ratings from potential newcomers could potentially distort the feedback of the entire sample. It should also be noted that cost engineers working for carmakers have a different view of their level of knowledge and have a different assessment of suitability to conduct fact-based negotiations than cost engineers working for carmaker suppliers. This may be due to the much more varied range of problems dealt with by carmakers, where suppliers only focus on a specific part of production. Thus, cost engineers working for suppliers may indeed have more knowledge to apply in fact-based negotiations, but only within a narrowly defined range of products. For these reasons, in the following detailed analysis, we will focus only on respondents with more than three years of experience and exclusively employed by carmakers.

We use a specifically defined set of respondents for detailed analysis using contingency tables and homogeneity tests of the underlying multinomial distribution. Indicative characteristics using median ratings of each type of cost for the research questions are shown in Tab. 5. Indirect costs (Material overheads and Manufacturing overheads) are visibly differentiated here, however there is also variability between direct cost types.

Tab. 5: Medians of assessment of different cost types for particular research questions

Cost type	Y_1	Y_2	Y_3	Y_4
Raw material cost	3	3	3	3
Direct labour cost	4	2	4	4
Machine cost	3	3	4	3
Material overheads	2	4	2	2
Manufacturing overheads	2	5	1	1

Before testing, we verified that the assumptions about the theoretical frequencies were met in all cases. The only case of theoretical frequencies less than 5 (but greater than 2) occurred in the case of the assessment of the risk that a supplier is successfully hiding not acceptable cost. Cost engineers were less likely

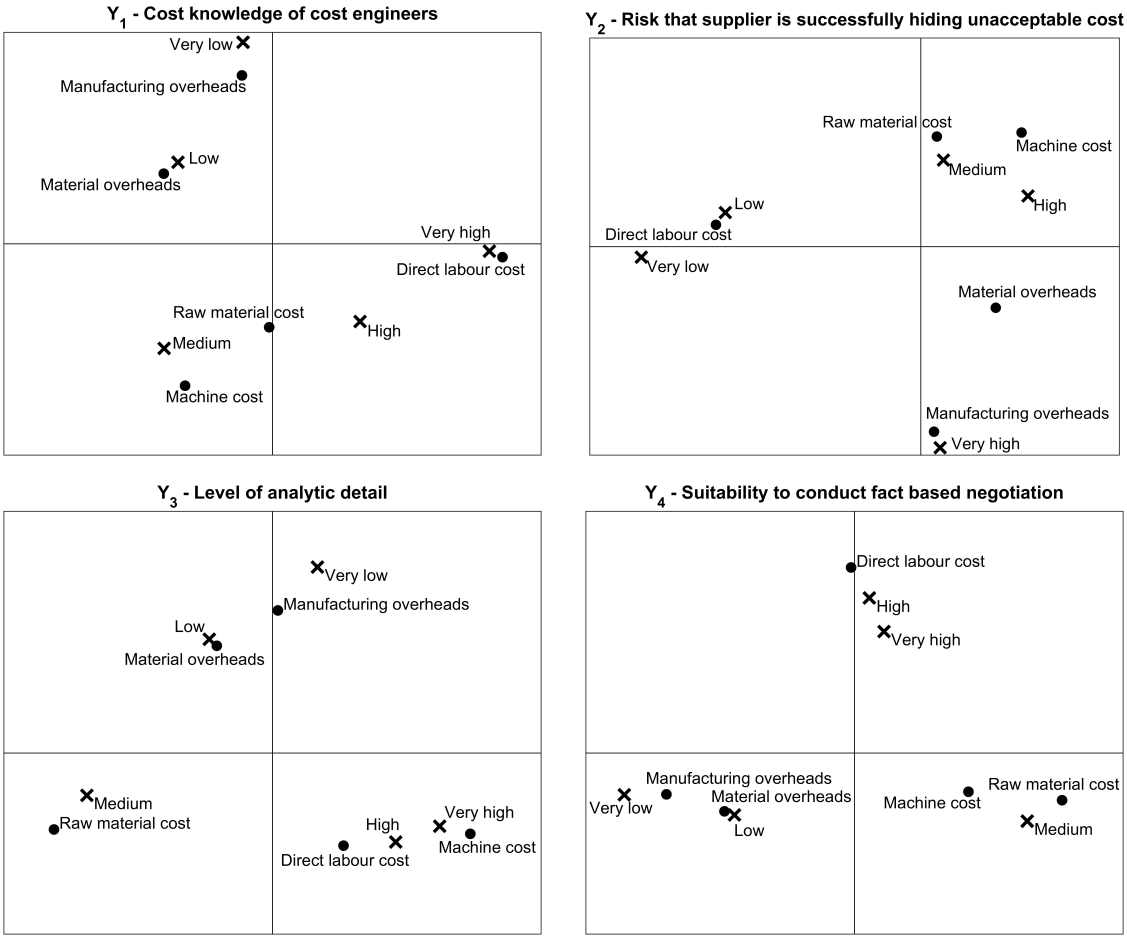

Fig. 1: Correspondence maps for tested hypotheses

to give a rating of "Very low" for all cost categories, reflecting their liability.

The null hypothesis that "Cost engineers evaluate their cost knowledge equally in the indirect cost categories as in the direct cost categories of their SCC" was rejected with $p < 0.001$ and $\chi^2 = 157.5$. We use the output of the correspondence analysis in the form of the correspondence map in Fig. 1, top-left graph, to explain where the differences lie for each type of cost. Knowledge of Direct labour cost is rated as very high, knowledge of Raw material cost as high to medium, and knowledge of Machine cost as a medium. In contrast, for indirect costs, cost engineers typically rate their knowledge of Material overheads as low and their knowledge of Manufacturing overheads as very low.

The next null hypothesis "Cost engineers rate the risk that a supplier is successfully hiding not acceptable cost or profit equally in indirect cost categories as in the direct cost categories of their SCC" was rejected with $p < 0.001$ and $\chi^2 = 214.7$. In Fig. 1, the top-right graph we can see that the low risk that a supplier is successfully hiding not acceptable costs is only associated with Direct labour costs. This risk is medium for Raw material cost and medium to high for Machine cost. For Indirect cost, the risk is high to very high for Material overheads, and for Manufacturing overheads the risk is typically very high.

After rejecting the null hypothesis "Cost engineers rate the level of analytic detail equally in indirect cost categories of their SCC as in direct

cost categories" ($p < 0.001$ and $\chi^2 = 240.0$) we can identify very high analytic detail for Machine cost, high for Direct labour cost and medium for Raw material cost. Manufacturing overheads are associated with very low and Material overheads with low analytical detail (Fig. 1, bottom-left graph).

The last null hypothesis "Cost engineers rate the suitability to conduct fact-based negotiations equally in indirect cost categories as in direct cost categories of their SCC" was also rejected ($p < 0.001$ and $\chi^2 = 205.0$). With the help of Fig. 1, bottom-right graph, we can conclude that the suitability to conduct fact-based negotiations is high for Direct labour cost and medium for Raw material cost and Machine cost. For indirect costs, we get that the suitability to conduct fact-based negotiations is low for Material overheads and very low for Manufacturing overheads.

The findings highlighted in this section have shown significant differences in how carmaker's cost engineers rate direct- compared to indirect cost categories to be considered in their Should Cost Calculations. Cost Engineers indicated to have a lower cost knowledge and to perceive a higher risk that suppliers hide unjustified costs in their price breakdowns. In addition to that cost engineers declared to perform a lower level of analytic detail and see a lower suitability to conduct fact-based negotiations in indirect compared to direct cost categories in their Should Cost Calculations.

5 DISCUSSION

Although statistically significant differences could be identified among the cost categories within the different investigated topics Y_i, the real causalities standing behind the identified statistical relationships are missing and subject to readers' interpretation. Hence the question might be raised as to why the specific pattern in ratings could be detected that finally resulted within the statistical findings. In order to answer this question, qualitative research is needed. Semi-structured interviews with experts in the field of cost engineering could explore and investigate the root causes and real causalities of the observed phenomena and can generate a deeper understanding. As a starting point for these interviews, the statistical findings of this paper could be presented to field experts to ask them to give their comments and interpretations. Furthermore, their knowledge could be used to generate ideas that focus on improving the calculation of indirect cost categories in Should Cost Calculations. A consolidation of their quantitative feedback could finally result in an analysis that identifies, addresses, and mitigates potential weaknesses of currently applied cost estimation techniques, that are utilized to consider material- and manufacturing costs in Should Cost Calculations.

Research conducted using a questionnaire survey may raise doubts about its relevance if the respondents are not sufficiently representative and competent. Random selection is a very important criterion to ensure the representability of survey data. For that reason, the previously introduced cost engineering channel on LinkedIn which is administered by the Society of Product Cost Engineering and Analytics has been recognized as the idle platform to place the electronic anonymous survey. Based on a review of the population it is obvious, that automotive cost engineers hold a large fraction of the total international community. The members of this community work in different worldwide regions, companies, and industries including the automotive industry. Since the channel is not focussing on a single carmaker or a certain group of carmakers it may be assumed that survey participants and dedicated responses were randomly selected from an international population of cost engineers, that are employed at different global acting automotive OEMs. Though the study was fully anonymous, and most survey participants provided anonymous feedback, some utilized the chance to provide their contact data, to indicate their willingness to attend potential follow-up interviews. That

way it may be at least indirectly confirmed that a minimum of 3 European and 2 US American carmakers are represented within the study. Furthermore, it may be confirmed that a broad mix of nationalities is represented in the study.

Similarly focused research by other authors is rarely available. Indirect costs are elaborated as a challenging problem for management in Deevski (2019), where a simple mathematical model of department cost allocation is introduced. The author concludes in line with our findings that indirect costs, in the sense of the most detailed allocation of costs, are "essential to place a competitive product on the market, take effective managerial decisions as well as monitoring company's performance and making strategic analysis". The automotive industry is currently facing enormous pressure on environmental friendliness and sustainability. Related to this are concepts such as full-cost accounting, which seeks to capture the full cost of production. In the context of the automotive industry, this issue has been addressed in a broad literature search by Jasinski et al. (2015). A better knowledge of indirect cost pricing will also help to assess total costs more accurately within full cost accounting.

6 CONCLUSIONS

Overall, we can conclude that the type of cost plays a significant role in the work of carmaker's cost engineers. The research questions posed in the introduction can be answered as follows:

- RQ_1: Knowledge of indirect cost categories is lower compared to the direct cost categories.
- RQ_2: Higher risk, that is not justified cost or profits are potentially hidden, is related within the indirect cost categories.
- RQ_3: Should Cost Calculations is performed for indirect cost categories with a lower level of analytical detail.
- RQ_4: Suitability to conduct fact-based negotiations is lower within indirect cost categories.

Our findings reinforce the impression of existing weaknesses in presently applied methods, that aim to consider supplier's material- and manufacturing overheads in Should Cost Calculations. The results of this paper indicate that there could be a lack of practical approaches that are better suited to decompose and calculate supplier overheads analytically and transparently. A similar gap can be recognized in academic literature. In the context of Should Cost Calculations academic literature is focussing strongly on analytic cost modelling in the context of direct cost categories while it ignores the need for analytic cost modelling within the indirect cost categories. The only recommendation that academic literature highlights to consider indirect cost in Should Cost Calculations is to apply percentage markups on the direct cost elements, without explaining in detail how to calculate these percentage markups analytically and transparently. This is a potential gap in academic research that needs to be filled. In addition to that it might be interesting if cost engineers face similar difficulties in considering appropriate costs for supplier's General and Administrative Expenses (SG&A) and Research and Development (R&D). Since this paper focused on material- and manufacturing overheads that incur within supplier's manufacturing facilities it might be interesting how cost engineers consider SG&A and R&D in their Should Cost Calculations. Since indirect labour might be not only a strong contributor to material-, manufacturing overheads but also to SG&A and R&D it might be interesting if similar results may be detected for these indirect cost categories.

Another implication of our results is that further research could be conducted on the analysis of existing cost estimation techniques without limiting the scope to Should Cost Calculations or a specific industry. The intention could be to identify and probably modify existing cost estimation techniques, which are better suited to consider indirect cost within

the cost engineer's SCC. These techniques might potentially increase cost engineers' cost knowledge and the level of analytic detail in which material- and manufacturing overheads are presently considered in Should Cost Calculations. In addition to higher cost knowledge and higher calculation accuracy, further positive side effects could be generated. An increased level of analytic detail might potentially result in a higher suitability to conduct fact-based negotiations. Similarly, it might be possible to lower the risk that suppliers hide not acceptable cost within indirect cost categories of their quote.

Improving methods for estimating indirect costs will entail additional demands for more data acquisition and, in particular, higher data quality concerning cost engineering. An inspiring and ambitious goal stated by Roy (2003) is "to capture and reuse human expertise or knowledge used during the development of a cost estimate". Xu et al. (2012) mention working with data under uncertainty as one of the important aspects of cost engineers' future work. These challenges, however, are confronted with the current problems with the quality of education in general (Chládková et al., 2021) and the declining level of mathematical knowledge, not only in the Czech Republic (Hampel and Viskotová, 2021), for example, but also in Germany (Büchele, 2020). An appropriate mix of statistically based courses integrated into the traditional curricula for engineers in the automotive industry will allow for desirable synergy effects leading to improved indirect cost estimation techniques.

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AUTHOR'S ADDRESS

Remo Rossi, Department of Statistics and Operation Analysis, Faculty of Business and Economics, Mendel University in Brno, Zemědělská 1, 613 00 Brno, Czech Republic, e-mail: xrossi@mendelu.cz

David Hampel, Department of Statistics and Operation Analysis, Faculty of Business and Economics, Mendel University in Brno, Zemědělská 1, 613 00 Brno, Czech Republic, e-mail: david.hampel.uso@mendelu.cz (corresponding author)

IMPACT OF THE COVID-19 PANDEMIC ON UNITED STATES' HOTEL PRODUCTIVITY: A MULTI-PERIOD ANALYSIS

Szilvia Vanessza Schalk-Nador[1]

[1] *Mendel University in Brno, Czech Republic*

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ABSTRACT

This paper uses the Malmquist Productivity Index to evaluate the impact of the COVID-19 pandemic on hotel productivity. It decomposes total factor productivity change (TFPC) into technical efficiency, pure and scale efficiency, and technical change to conclude on productivity growth before and after the outbreak of the pandemic. 112 hotels in four cities of the United States between 2011–2021 were subject to the analysis, using a multi-input (room, labor, and F&B costs) multi-output (accommodation, F&B, and total revenue) DEA-Malmquist model. The pandemic did not have an adverse effect on hotel productivity change, mainly due to the developments attributed to technological advancements. The paper offers crucial managerial implications. The results of the analysis emphasize the prominence of investment in technology to sustain productivity levels. It supports managers with strategy development and offers decision makers a wider overview of the sector.

KEY WORDS

COVID-19 pandemic, productivity, Malmquist productivity index, technical efficiency change, technical change

JEL CODES

D21, L83, M10

1 INTRODUCTION

The COVID-19 pandemic is among the most impactful events of this century resulting in border closures, lockdowns, and shutdowns of hospitality establishments (Zenker and Kock, 2020). Due to the severe repercussions of the pandemic that hit the prospering US hotel industry, the sector had to respond immediately if hotels were to stand a chance of survival (Škare et al., 2021). High operating costs, high break-even points, and the need to generate revenue typified an industry that was facing new challenges: customers' fear of staying at ho-

SCHALK-NADOR, Szilvia Vanessza. 2024. Impact of the COVID-19 Pandemic on United States' Hotel Productivity: A Multi-Period Analysis. *European Journal of Business Science and Technology,* 10 (1): 107–122. ISSN 2694-7161, DOI 10.11118/ejobsat.2023.016.

tels, reluctance to use in-house F&B offerings, customer limitations to ensure social distancing, and the need to improve employee training in matters of health and safety (Gursoy et al., 2020). Thus, research that focuses on improving the bottom line is crucial to aid managers counterbalance the new challenges faced by this industry (Gursoy and Chi, 2020). The pandemic led to plummeting sales, diminished occupancy rates, employee redundancies, and lower profit levels, calling for immediate action (American Hotel & Lodging Association, 2022). It is unsurprising that only productive companies can increase their outputs without incurring additional input costs. Increased productivity transforms into higher earnings (Assaf et al., 2011) which aim to counterbalance pandemic-induced effects. Therefore, reaching a superior level of productivity is important in the service sector (Brown and Dev, 2000). However, it is worrisome that the hospitality industry has been characterized by low productivity levels (Martins et al., 2020; McMahon, 1994; Sigala et al., 2005). Hence, this study aims to understand the impact of the global epidemic on productivity levels, an important contributor to hotels' bottom lines (Brown and Dev, 2000).

Productivity, the extent to which inputs can be effectively converted into outputs, is measured as the ratio of a property's output to its inputs (Baker and Riley, 1994). The level of productivity and marginal productivity of a given input determines the rate of survival, implying that productivity is the key to continued existence (Syverson, 2011). Furthermore, the quality of output, which is an important determinant of productivity, is challenging to quantify (Assaf and Agbola, 2011). As a reaction to this widely accepted problem, the United Nations World Tourism Organization (UNWTO) has made productivity issues one of the top priorities to attract researchers' attention (Chatzimichael and Liasidou, 2019).

To determine productivity levels TFPC – which is split into two equally important parts, (technical) efficiency change (EC) and change in (frontier) technology, or technical change (TC) – is computed. The improvement potential in EC designates the possibility of an overall enhanced performance between two time periods and describes the efficiency with which inputs can be converted into outputs and, hence, the capabilities of managers (Färe et al., 1994). Improvement suggested by TC shows the slack portion; that is, it identifies the "under-produced output or over-utilized input" (Avkiran, 2006) in the application of current technologies (Färe et al., 1994), as the model hypothesizes that "businesses do not fully utilize existing technology" (Kim, 2011), and thus identifies the technological progress.

The major determinants for the change in technical efficiency were presumed to be related to human capital, training available to employees, best practices followed by line managers, and the input mix. However, technical progress, was influenced by investment in employed capital, research and development, and improvement of available capital. While this may be true for the manufacturing, construction, or trade industries, Kim (2011) notes that it would be incorrect to assume that the same determinants are valid in the hospitality industry. The application of technological solutions is not only in line with the demands of post-pandemic customers seeking less human contact, but also aids in improving productivity levels through its influence on TC. Technological innovations include self-service kiosks, the application of QR codes, digital room keys, robots that make human interactions redundant, (Gursoy et al., 2020) and artificial intelligence. This study aims to understand the importance of technology on productivity levels in relation to the pandemic.

Hence, this study discusses the following research questions:

- RQ_1: Did the pandemic influence productivity levels?
- RQ_2: Which factors drove TFPC more, EC or TC?

2 THEORETICAL FRAMEWORK

2.1 COVID-19 and the United States' Hotel Industry

The hotel industry was severely hit by the pandemic as border closures made it impossible to travel for 90% of the global population (Gössling et al., 2021). Although the US did not issue unified "shut down" orders, a lack of willingness to travel and country-wide lockdowns led to plummeting occupancy levels, skyrocketing rates of unemployment, tremendous revenue loss (American Hotel & Lodging Association, 2022) and a significant decline of total US exports related to international visitor spending (World Travel & Tourism Council, 2020). Although it is clear that since 2020, a recovery can be observed, a full recovery to pre-pandemic levels is only expected by 2025 (STR, 2021) due to a variety of factors that have appeared during the pandemic: the ongoing presence of hybrid events resulting in lower banqueting spending, the accumulation of debt still not being offset, the elimination of single-day business travel due to enhanced video-conferencing options, and ongoing inflation levels (American Hotel & Lodging Association, 2022). Following the guidelines of PRISMA, this study uses a compilation of pandemic related research using pre-selected keywords, as shown on Tab. 1, similar to the work of Davahli et al. (2020).

The methodology used to compile the table above consisted of three steps: (1) Definition of relevant keywords. (2) Filtering of search results. (3) Removal of non-relevant articles. Three separate searches were conducted using the following keywords: (1) COVID-19 AND hospitality industry (2) COVID-19 AND hotel industry (3) COVID-19 AND tourism industry. As illustrated in Tab. 1, existing papers can be categorized into various groups. First, there are papers that describe and measure the impact and extent of the repercussions experienced by the hotel industry. Second, other papers propose distinct actions, such as strategies to restore hospitality operations to their pre-pandemic levels. Third, some papers take it a step further and employ scenario modelling to suggest different outcomes. Finally, certain papers compare the most recent pandemic with previously experienced health crises. The current paper aims to enrich the first category of literature mentioned above by seeking to understand and measure the impact that the hotel industry experienced due to the pandemic.

2.2 The Impact of Crises on Productivity Growth

The importance of understanding and measuring the impact of the COVID-19 pandemic is highlighted by the fact that the current global epidemic is not the first crisis humankind has faced. Natural disasters, socio-political tensions, and financial and health crises are well-documented phenomena that have been explored in substantial research. Looking back at the impact of previous crises, similar patterns and theories can be recognized that explain the circumstances that the world is facing today (Zenker and Kock, 2020). Considering the fact that the pandemic provoked an economic crisis similar to the global financial crisis in 2008, previous studies analyzing the effects of the economic recession offer basic information about the expected behavior of productivity development during a crisis. Hotels have exhibited incessant resilience against previous financial and health crises and have rebounded quickly, mainly because of their capability to improve TC levels (Peypoch and Sbai, 2011). Slovenian hotels that failed to introduce innovative technologies experienced negative productivity growth during the economic crisis of 2008–2010, even though they showed EC advancements (Frančeškin and Bojnec, 2023). However, crisis-induced organizational modifications have dependably contributed to improving cumulative productivity levels (Meriküll and Paulus, 2024).

Extant studies are not in agreement about the effect of the COVID-19 pandemic, yet they agree on the importance of technological advancements in driving productivity levels. Certain findings demonstrate that the global

Tab. 1: Summary of COVID-19-related research within the hotel industry (extract)

Author(s)	Title	Industry segment	Location	Approach
Ablanedo-Rosas et al. (2023)	COVID-19 impact on the operational efficiency of a downtown hotel	Hotel Industry	United States	Discussing resumption of activities during and after the pandemic
Aigbedo (2021)	Impact of COVID-19 on the hospitality industry: A supply chain resilience perspective	Hospitality Industry	United States	Reporting the impacts of the COVID-19 pandemic
Antonio and Rita (2021)	COVID 19: The catalyst for digital transformation in the hospitality industry?	Hospitality Industry	Portugal	Discussing resumption of activities during and after the pandemic
Bagnera and Stewart (2020)	Navigating hotel operations in times of COVID-19	Hotel industry	Global	Discussing resumption of activities during and after the pandemic
Bakar and Rosbi (2020)	Effect of Coronavirus disease (COVID-19) to the tourism industry	Supply-demand in tourism industry	Global	Developing simulation & scenario modelling
Cajner et al. (2020)	Tracking labor market developments during the COVID-19 pandemic: A preliminary assessment	Hospitality job loss	United States	Measuring the impact of COVID-19
Gerwe (2021)	The Covid-19 pandemic and the accommodation sharing sector: Effects and prospects for recovery	Accommodation sharing sector	Global	Discussing resumption of activities during and after the pandemic
Gössling et al. (2021)	Pandemics, tourism, and global change: A rapid assessment of COVID-19	Airlines, Accommodation, sports events, restaurants, cruises	Global	Comparing COVID-19 with previous public health crises
Hoque et al. (2020)	The effect of Coronavirus (COVID-19) in the tourism industry in China	Inbound and outbound flights, hotel industry, restaurant industry	China	Reporting the impacts of the COVID-19 pandemic
Hu and Lee (2020)	Airbnb, COVID-19 risk and lockdowns: Global Evidence	Hotel industry	China	Reporting the impacts of the COVID-19 pandemic
Kim et al. (2021)	COVID-19 and Hotel Productivity Changes: An Empirical Analysis Using Malmquist Productivity Index	Hotel Industry	United States	Discussing resumption of activities during and after the pandemic
Kim et al. (2022)	What to Sell and How to Sell Matters: Focusing on Luxury Hotel Properties' Business Performance and Efficiency	Hotel Industry	Global	Discussing resumption of activities during and after the pandemic
Ocheni et al. (2020)	Covid-19 and the Tourism Industry: Critical Overview, Lessons, and Policy Options	Aviation, Cruise-shipping, hospitality industry	Global	Discussing resumption of activities during and after the pandemic
Ozdemir et al. (2021)	Quantifying the economic impact of COVID-19 on the U.S. hotel industry: Examination of hotel segments and operational structures	Hotel Industry	United States	Reporting the impacts of the COVID-19 pandemic
Rodríguez-Antón and Alonso-Almeida (2020)	COVID-19 Impacts and Recovery Strategies: The Case of the Hospitality Industry in Spain	Hospitality Industry	Spain	Discussing resumption of activities during and after the pandemic
Rosemberg (2020)	Health and safety considerations for hotel cleaners during COVID-19	Hotel industry	Global	Reporting the impacts of the COVID-19 pandemic
Scholz et al. (2022)	Green management implementation: A case of the Bulgarian hotel market	Hotel industry	Bulgaria	Discussing resumption of activities during and after the pandemic
Štumpf et al. (2021)	Restart of hospitality and tourism	Hospitality Industry	Czech Republic	Developing simulation & scenario modelling
Yang et al. (2020)	Coronavirus pandemic and tourism: Dynamic stochastic general equilibrium modelling of infectious disease outbreak	Tourism demand	Global	Developing simulation & scenario modelling
World Health Organization (2020)	Operational considerations for COVID-19 management in the accommodation sector: Interim guidance 31 March 2020	Hotel industry	Global	Discussing resumption of activities during and after the pandemic

epidemic did not have a negative effect on productivity, mainly driven by TC and optimal efficiency of scale. Investments in service and process improvements drove productivity during the pandemic, supporting its rebound after the outbreak (Tzeremes, 2021). Analysis conducted in the Euro-area has revealed aggregate productivity enhancement due to a proportionally lower decrease in output compared to invested working hours, and the increasing dominance of technologies and remote work stimulating productivity (Criscuolo, 2021). Productivity deteriorated with diminishing technological advancements, while EC improved through effective resource management such as streamlined cleaning processes, lower wages, reduced team size, and partnerships with top hygiene brands. Immediate effects from recommended hygiene innovations like electrostatics and ultraviolet light may not be anticipated (Kim et al., 2021).

2.3 The Importance of Productivity's Components – EC and TC

While authors may not agree about the components driving productivity during the pandemic, it is known that productivity is important during a downturn, and improving it contributes to better profitability, while during an economic upsurge, future success can be preserved. Productivity can be enhanced through higher skilled workers, better equipment, automation, "do-it-yourself" solutions for guests and through making informed strategic decisions, which include ownership structure, management arrangement, hotel categorization, and the size of property (Brown and Dev, 1999). Considering the importance of enhanced productivity and that the hospitality industry is notorious for low levels of productivity (Johns et al., 1997), the potential findings of this study may be crucial to the industry. Especially since it seems that, considering various scenarios, the rebound of tourism demand may be on the pessimistic side, as demonstrated by the scenario modelling undertaken by Štumpf et al. (2021). Notably, there is also a growing body of literature identifying the determining elements of productive operations (Aissa and Goaied, 2016; Peypoch et al., 2021). While EC represents the technical efficiency change due to skillful managers, improved management of the booking channels, and training of employees improving productivity so that hotels can catch up to the production frontier (Kim, 2011), improvement through TC is achieved by the application of revolutionary technical solutions, automation, and digitalization of manual processes, which lead to a shift in production functions (Färe et al., 1994).

Previous research supports the importance of technological advancement in productivity improvement. For example, after analyzing hotels in 30 Chinese provinces between 2005 and 2015, Peypoch et al. (2021) found that the category of a hotel influences its productivity change. Hotels with lower star ratings demonstrated better progress in TC than their higher-rated counterparts, since the initial levels of technological progress were lower than those of higher-category hotels. While the extent of productivity change was different across hotel categories, the importance of TC was confirmed, as this was the main driver of productivity, independent of the hotel category. Similar conclusions were reached by Barros (2005), Chatzimichael and Liasidou (2019), and Kim (2011). Chatzimichael and Liasidou (2019) examined TFP growth in the hotel sector across 25 European countries from 2008 to 2015 and concluded that, despite the fact that TC was driving positive TFPC, it is still considerably superior in other economic sectors compared to the hotel industry. Low levels of improvements in EC lead to plummeting productivity results, while scale efficiency (SE) shows that hotels do not operate at an optimal scale. Notably, low technical efficiency scores may be due to inefficiencies at an operational level and poor managerial decisions. That is, although hotels invest in technology, inputs and outputs fail to exhibit an optimal balance.

Barros (2005) also confirmed the importance of TC after analyzing 42 Portuguese hotel properties during the period 1999–2001. In Kim's (2011) study of 147 hotels operating in the

Malaysian market, the author concluded that although the size of a hotel is an important determinant since the largest hotels demonstrated the best results, TFPC was dominated by technical advancements and worsened by technical efficiency results independent of the size of the respective hotel. Goncalves's (2013) study on French ski resorts found that TFP components had negative impacts on productivity due to inadequate investment in new infrastructure and an aging inventory, resulting in decreasing TC. Additionally, mismanagement of operating costs and high employee turnover contributed to declining EC levels. These studies highlight the pivotal role of technology in long-term productivity. TC, being the primary driver, hinges on hotels' innovation capabilities for future success.

3 METHODOLOGY AND DATA

Productivity growth is analyzed using the data envelopment analysis (DEA)-Malmquist model, which has an advantage over the traditional DEA method in that it engages dynamic time-series data. This linear programming method was used to construct the Malmquist Productivity Index (MPI), which was designed to measure productivity change over time (Assaf et al., 2011) by constructing a non-parametric piecewise production frontier over the data.

Productivity is measured as the ratio of vertical and horizontal distances between two time periods, vertical distance implying an "output expanding orientation," horizontal distance in turn standing for an "input-conserving orientation" (Fried et al., 2008, p. 59). Research notes that, especially within the hotel sector, technical efficiency is a reasonable measure – which is not influenced by underlying costs or prices – to determine a hotel's ability to convert inputs into outputs (Avkiran, 2006; De Jorge and Suárez, 2014). TC describes the need for technological improvement; thus, the extent of development needs to become more competitive and achieve a higher output by shifting the frontier, without changing the number of inputs. TFPC is the multiplication of these two indices, either of the two, or both, being able to explain the improvement in productivity over time (Färe et al., 1994).

The MPI index was generated by calculating the best-fit frontier using DEA technology, since it allows for the "estimation of TFP as a Malmquist index" (Barros and Alves, 2004). When constructing the indices, distance functions were created using both input and output values. Following Färe et al. (1994), the output-oriented Malmquist index was constructed as follows in period t and in time period $t+1$:

$$\begin{aligned} M_o^t &= \frac{D_o^t\left(x^{t+1},y^{t+1}\right)}{D_o^t(x^t,y^t)} \\ M_o^{t+1} &= \frac{D_o^{t+1}\left(x^{t+1},y^{t+1}\right)}{D_o^{t+1}(x^t,y^t)} \end{aligned} \tag{1}$$

As previously mentioned, the geometric means of the two indices are constructed as follows:

$$M_o\left(x^{t+1},y^{t+1},x^t,y^t\right) = \left[\left(\frac{D_o^t\left(x^{t+1},y^{t+1}\right)}{D_o^t(x^t,y^t)}\right)\cdot\left(\frac{D_o^t\left(x^{t+1},y^{t+1}\right)}{D_o^t(x^t,y^t)}\right)\right]^{\frac{1}{2}} \tag{2}$$

This can be noted as follows: to clearly see EC and TC,

$$M_o\left(x^{t+1},y^{t+1},x^t,y^t\right) = a\cdot b,$$

where

$$a = \left(\frac{D_o^{t+1}\left(x^{t+1},y^{t+1}\right)}{D_o^t(x^t,y^t)}\right),$$

$$b = \left[\left(\frac{D_o^t\left(x^{t+1},y^{t+1}\right)}{D_o^{t+1}(x^{t+1},y^{t+1})}\right)\cdot\left(\frac{D_o^t\left(x^t,y^t\right)}{D_o^{t+1}(x^t,y^t)}\right)\right]^{\frac{1}{2}}$$

which is equal to the following decomposition, the most common version suggested by Färe et al. (1994):

$$\frac{D_o^{t+1}\left(x^{t+1},y^{t+1}\right)}{D_o^t(x^t,y^t)}\cdot \cdot\left[\left(\frac{D_o^t\left(x^{t+1},y^{t+1}\right)}{D_o^{t+1}(x^{t+1},y^{t+1})}\right)\cdot\left(\frac{D_o^t\left(x^t,y^t\right)}{D_o^{t+1}(x^t,y^t)}\right)\right]^{\frac{1}{2}} \tag{3}$$

where M_o represents total factor productivity (TFP) indicating output orientation, D are

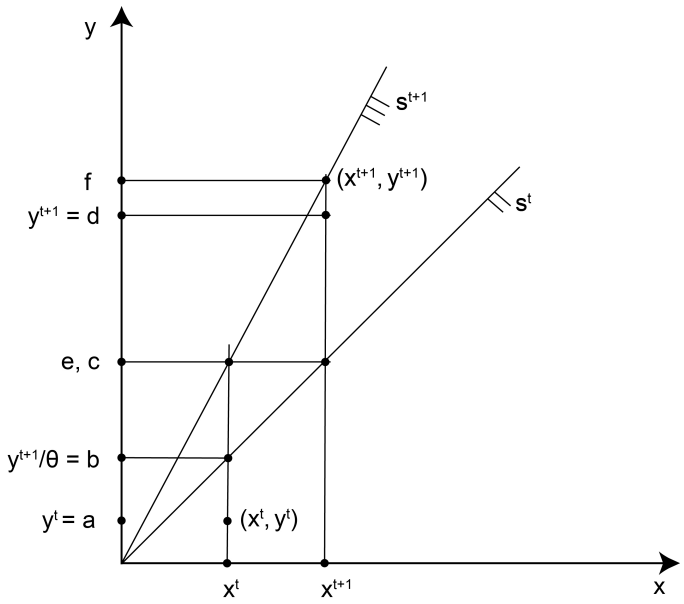

Fig. 1: The Malmquist output-based index of total factor productivity and output distance functions (Färe et al., 1994)

output distance functions, x represents all the inputs, y represents all the outputs for periods t and $t+1$, a stands for the EC between two chosen periods, and b denotes the geometric mean of TC. The EC can be further divided into scale efficiency change (SEC) and pure efficiency change (PEC). The former describes the extent to which the given decision-making unit (DMU) is close to or deviates from its most efficient scale size, and thus can produce at an optimal scale and at constant returns to scale. Hence, this measure considers the optimum size chosen previously to avoid inefficiencies from choosing a company that is either too large or too small. The product of these two change indices amounts to an efficiency change.

Therefore, it can be concluded that maximum productivity is reached when $D_o^t(x^t, y^t) = 1$, for which (x^t, y^t) must be located on the constructed technology frontier. Fig. 1 shows that when (x^t, y^t) are below the efficient production frontier S^t, they are technically inefficient. The frontier can be created by utilizing the "reciprocal of the greatest proportional increase in output(s) given input(s), such that output is still feasible" (Färe et al., 1994), which in the figure below is shown at y^t/θ^*, representing the "best practice" or greatest productivity. It is important to note that when constructing S^t for any time period $t = 1, \ldots, T$, where $x^t \in \mathbb{R}_+^N$, inputs are used to create $y^t \in \mathbb{R}_+^M$; therefore, $S^t = \left\{(x^t, y^t) : x^t \text{ can produce } y^t\right\}$. Two different time periods, t and $t+1$, were observed; thus, the two distance functions are as follows: $D_o^t\left(x^t, y^t\right)$ and $D_o^t\left(x^{t+1}, y^{t+1}\right)$. The values (x^{t+1}, y^{t+1}) depict the "maximum proportional change in outputs" demonstrated by the distance function still "feasible in relation to the technology at t" (Färe et al., 1994). As illustrated below, S^t shows that a technical change occurred, leading to a shift in the production frontier S.

If $M_o^{t+1}\left(x^{t+1}, y^{t+1}, x^t, y^t\right)$ results in a value higher than 1, productivity growth is confirmed, while a value that equals 1 suggests stagnation, and a value lower than 1 suggests a decline in productivity levels.

3.1 Dataset

Longitudinal data between 2011 and 2021 were collected to analyze productivity levels. The data for the first analysis commences in 2011, the year during which the hotel industry started to rebound from the global financial crisis and ends in 2019, the last full year prior to the

Tab. 2: Structure of the sample (based on data provided by STR)

Variable	Code	Definition	Hotels	Observations
Urban	1	Densely populated location in a large metropolitan area	27	243
Suburban	2	Suburb of metropolitan area	36	324
Airport	3	Proximity to an airport	21	189
Interstate/Motorway	4	Proximity to a highway	0	0
Resort	5	Main source of revenue derives from leisure travel through the hotel's resort location	28	252
Small metro/town	6	Areas with either smaller population or limited services, in remote locations populated with less than 150,000 people	0	0
Size 1	1	<75 rooms	0	0
Size 2	2	75–149 rooms	35	315
Size 3	3	150–299 rooms	43	387
Size 4	4	300–500 rooms	18	162
Size 5	5	>500 rooms	16	144
Less than 10	1	Less than 10 years	24	216
Between 11 and 20	2	Between 11 and 20 years	43	387
Between 21 and 30	3	Between 21 and 30 years	35	315
More than 31	4	More than 31 years	10	90
Luxury	1	Top 15% average room rates	17	153
Upper-upscale	2	Next 15% average room rates	31	279
Upscale	3	Next 15% average room rates	36	324
Upper midscale	4	Next 15% average room rates	5	45
Midscale	5	Next 15% average room rates	0	0
Economy	6	Lowest 20% average room rates	23	207
Chain Owned and/or Managed	1	Properties are branded and operated by the chain	90	810
Franchised	2	Third party operator, which in exchange for certain fees is entitled to use the 'brand name, marketing and reservation services, etc.'	18	162
Independent	3	Independent hotel, non-affiliated	4	36

Tab. 3: Descriptive statistics of the variables for the 112 hotels, 2011–2019 (based on data provided by STR)

Variable	Obs.	Mean	Std. Dev.	Min.	Max.
Input variables					
Total room related expenses	1,008	4,046,892	4,696,496	203,691	29,041,947
Total labor costs	1,008	7,393,566	9,831,560	266,710	52,419,687
Total F&B costs	1,008	3,258,845	5,533,453	−38	32,448,883
Output variables					
Total sales	1,008	20,489,532	23,942,835	981,646	128,339,827
Accommodation revenue	1,008	14,474,530	15,130,263	967,311	97,404,329
F&B revenue	1,008	4,794,054	8,471,783	−2,368	49,933,329

outbreak of the pandemic. The second analysis compares the first two COVID-19 years with the two years prior to the outbreak. The author is grateful to STR LLC (STR), who provided all data used. Brand names, hotel operators, and property owners were omitted to honor the confidentiality agreement with STR. After the exclusion of STR categories for which no data were received, a sample size of 112 hotels was confirmed, which resulted in 1,008 observations during the first nine years of analysis, whereas for the second analysis, 112 hotels were used annually. Tab. 2 shows the structure of the sample.

Tab. 3 shows the variables used to estimate productivity scores based on data availability, as well as following previous studies. Data are expressed in USD.

4 RESULTS

4.1 Estimation of Productivity – Malmquist Index Prior to the Pandemic

Tab. 4 shows the results of the Malmquist productivity analysis. The index showing TFPC over the years 2011–2019 was decomposed into efficiency change and technical change; the former is further broken down into pure technical efficiency and SE change. Between 2011 and 2019, the cumulative productivity of the 112 hotels increased by 2%. This is partly due to technological development, implying the better use of existing technologies or system-related innovations, leading to a shift in frontier technology. This implies an improvement in efficiency, possibly due to superior investment planning or better organization of hotel operations. For the years during which efficiency change and technical change coincided, the best relative performance was achieved.

The value of technical change amounts to 1.013, which implies the application of advanced digital administrative tools and the accomplishment of technological milestones, such as a shift to self-service check-in processes or the introduction of CRM systems for better retention of customer data. With a mean value of 1.007, efficiency change is the less significant driver for TFP improvement, yet the > 1 result implies that the conversion of inputs into outputs occurred in a more efficient manner compared to the previous year and that the catch-up component is on the decline. This entails the dynamic allocation of employees within the departments based on each subdivision's requirements or a lower number of employees for the productive years, resulting in a better utilization of inputs. However, better results can be attributed to a longer average duration of stay, improved number of guests through better marketing, better overbooking practices, and better management of cancellation policies. In cases where efficiency expansion and technological deterioration coincided (only between 2014/2015 and 2017/2018), organizational advancements were almost certainly not achieved due to the application of new technologies. During these years, delays in adopting new technologies or the lack of employee training may have led to these results. For 2015/2016 and 2018/2019, the change in efficiency was negative, while technological improvements were observed. This may imply that some businesses failed to adopt the latest advances or displayed a lack of technical expertise in these years, possibly due to a shortage of training for the new systems. Furthermore, a principal-agent problem may be observed, implying a mismatch in management empowerment (Dalbor and Andrew, 2000). This may also be attributed to an asymmetric incentive system for employees, or a lack of incentives to improve output levels (Abdullah and Hamdan, 2012).

Considering the building blocks of efficiency change between 2011/2012, 2012/2013, and 2016/2017, an improvement in pure technical efficiency change was detected, implying that in other cases, attainable boundaries were not reached. In two years – 2015/2016 and 2018/2019 – the efficiency of scale pulls down overall efficiency change, implying a possible

Tab. 4: MPI summary of the annual means (based on data provided by STR)

Year	Efficiency change	Technical change (TE)	Pure technical efficiency (PTE)	Scale efficiency (SE)	Total factor productivity change (TFPC)
2011/2012	1.015	1.044	1.005	1.010	1.059
2012/2013	1.050	1.003	1.041	1.009	1.054
2013/2014	1.001	1.016	0.987	1.014	1.018
2014/2015	1.007	0.980	0.977	1.031	0.987
2015/2016	0.984	1.032	0.993	0.991	1.015
2016/2017	1.008	1.009	1.003	1.005	1.017
2017/2018	1.019	0.989	0.998	1.020	1.008
2018/2019	0.976	1.031	0.993	0.982	1.006
Mean	1.007	1.013	1.000	1.008	1.020

deficit in the size of the hotels investigated. This is further supported by the means of both pure and scale efficiency, where it becomes clear that the main contributor to efficiency change is scale efficiency, implying a failure to improve the organization of the inputs by managers related to the production process; hence, a negative learning curve is obtained. This may be due to a lack of marketing activities initiated, failure to demonstrate advancement in the quality of the hotel product offered, or other related improvements in organizational aspects associated with hotel management. For the years during which the value for efficiency related to hotel size is > 1, even smaller hotels could achieve economies of scale by showing an optimal relationship between demand and supply proportionally, or by having scaled down overhead services by sharing this function. It can be reasoned that this was due to the characteristics of the sample, which did not contain the smallest hotel category (0–75 rooms) and may have been the reason for the scale efficiencies showing relatively good results.

4.2 Estimation of Productivity – Malmquist Index During the Pandemic

Tab. 5 displays the results of the productivity analysis between the two pre-COVID years and two years after the outbreak of the pandemic.

Between 2018 and 2021, cumulative productivity of the 112 hotels increased by 9.8%. This growth can be mainly attributed to the performance of the analyzed hotels during the pandemic. There was an irregularly high increase in 2019/2020 (20.9%), which may be attributed to several factors. First, there was a large reduction in headcount in numerous hotels, while the Employee Retention Credit under the CARES Act strongly supported companies and individuals within the sector through a refundable tax credit of 50%, aiding the retention of employees in the sectors highly affected by the pandemic (Internal Revenue Service, 2022). Furthermore, numerous hotels offered limited services (e.g., minimizing non-monetarized services usually performed for regular guests, eliminating stay-over housekeeping services), leading to the complete elimination of costs associated with these labor-intensive services for a certain period of time. However, the large increase in the years 2019/2020 is mainly due to technical change (19%), hence the changes in technology deserve an improved focus. In both 2018/2019 and 2019/2020, TFPC was positive, mainly influenced by the positive technical change. This implies that, in these years, employees managed to use existing technologies in a better way and that innovations may have been introduced. This is in line with the expectation for 2019/2020, since many enterprises, including hotel companies, used the unexpected standstill for employee training and technology upgrades, when the lack of guests allowed for these improvements. In the following year, 2020/2021, only two

Tab. 5: MPI summary per year (based on data provided by STR)

Year	Efficiency change	Technical change (TE)	Pure technical efficiency (PTE)	Scale efficiency (SE)	Total factor productivity change (TFPC)
2018/2019	0.976	1.117	0.993	0.982	1.090
2019/2020	1.016	1.190	1.007	1.009	1.209
2020/2021	1.022	0.982	0.993	1.029	1.004
Mean	1.004	1.093	0.998	1.007	1.098

elements of TFPC were not positive, one of them being technical change, which is probably due to the high increase the year before and new employees hired mid-2021 – when domestic travel started to pick up – lacking the knowledge of operating existing and new technologies.

However, it must be noted that the overall efficiency change is slightly positive with a mean value of 1.004. This improvement is mainly due to the last year of analysis (2020/2021). These results may be due to the lower price sensitivity of guests arriving through domestic travel, as they would have been saving during the pandemic-imposed lockdowns. Furthermore, hotels may have used the time in 2020 to improve operations-related processes. Because of the lower number of hotel staff, it should also be noted that employees had to help out in departments other than their designated placement, leading to a more efficient use of existing resources rather than hiring and training new staff members. Similar to the pre-pandemic analysis, no period was observed in which both efficiency and technical change were positive. The mean value of technical change amounts to 1.093, which is the largest improvement among all the categories. This implies that hotels managed to reach technological milestones, resulting in a shift in the technological frontier. This may have included automating check-in processes, the use of mobile device-based keys, introducing QR codes for orders in hotel restaurants, just to name a few.

5 DISCUSSION AND CONCLUSIONS

This study measured the development of MPI during the pandemic in the US. MPI ensures that not only momentary performance is measured, but also that any change in performance is observed. Prior to the pandemic, a cumulative productivity increase of 2% was observed. By decomposing TFPC, it is concluded that the advancement was mainly due to TC, leading to a shift in the technology frontier. As for the building blocks of EC, the main negative driver was SE, which implies that hotels do not operate at an optimal scale. The first year of the pandemic (2020) drove productivity improvement in the period 2018–2021, as hotels were performing better by 9.8%. The improvement was mainly influenced by the technological innovations that hotels were forced to pursue. Ultimately, the research question is answered: the pandemic did have a positive impact on productivity levels, mainly due to the technological innovations that hotels were forced to adopt, and hence TC is the stronger driver of TFPC.

These findings are in line with previous studies and propose that technological innovations are crucial for rebounding from a crisis. The study's results can serve as a foundation for managers and strategists to enhance profitability by identifying and addressing weaknesses using the MPI. The productivity index is a powerful tool for tracking performance over time and identifying areas of weakness to enhance profitability.

5.1 Practical Implications

Decision-makers within the hotel industry should make it their priority to strive for productivity driven by service innovations, as this is crucial to remain competitive throughout crises that impact industries (Gössling et al., 2021). The requirements of the hotel industry are constantly changing as every competitor strives to achieve larger market share in pursuit of enhanced profitability. This study's findings provide indicators and benchmarks to strive for; however, industry managers who are tasked with implementing changes for better performance will require guidance to achieve these.

The findings clearly demonstrate that technological innovation drives productivity. To achieve revolutionary results in this area, managers should approach tech companies regarding collaboration and exclusive rights to field test pilot projects. Accordingly, hotels can test revolutionary technologies and systems, creating a win-win scenario for both parties. Hotels would save money in applying yet unknown and costly technologies, and actively participate in improving, thus creating new industry-specific technologies. Simultaneously, tech companies would receive first-hand feedback from field experience, speeding up the development process of new technologies.

Furthermore, it is crucial to forecast the future needs of travelers and re-evaluate hotels' current business models, as it is possible that they will no longer be sustainable within the next 10–15 years. Hence, to ensure continuous technological improvement that drives productivity, close collaboration with local and international tourist boards is recommended to receive guidance on market-related changes.

As hospitality is often referred to as a people's business, technological implementation needs to be undertaken carefully, as this may lead to further loss of staff, opening an even wider gap in the lack of a skilled workforce or creating negative guest sentiments leading to lower booking rates; hence, the co-existence of high-tech and a personal touch is crucial (Davari et al., 2022). Nevertheless, with innovative technology such as artificial intelligence (Im and Kim, 2022), even lower skilled staff can be assisted in day-to-day business, and guest satisfaction may be improved.

However, improving technical efficiency should not be neglected, as it can further drive TFP levels. One of these aspects is actively using crisis management tools, which are becoming increasingly important since changing cultural behavior necessitates actively working with these rather than simply ignoring them (Kim et al., 2021). These tools may have existed previously, especially in chain-affiliated hotels, but were mostly ignored as the industry was not facing a crisis to the extent presented by the COVID-19 pandemic. The implementation of such tools may not have an immediate impact; hotels benefit from these in urgent cases whenever a crisis arises and losses appear to a greater extent, thus managing challenges better than competitors. The use of these tools may be crucial to positively influence EC and to avoid the currently prevalent drastic short-term decisions taken to keep hotels financially stable, resulting in pay cuts, reduction of the workforce, and unpaid leave.

Hotels can also implement short-term actions to improve productivity levels. Managers must re-evaluate the allocation of available resources and become smarter to optimize the bottom line. One tool for this could be the tax saving aspect, which could also benefit the notorious post-COVID-19 staff shortage prevalent in the hotel industry. Hotels could work together with governmental organizations to find suitable employees among the government-subsidized group of employees (e.g., apprentices, the elderly, veterans, etc.). Thus, hotels would not only drive productivity levels through tax-saving effects (Kim et al., 2021) but would also contribute positively to improving community-relations. Further immediate actions have included the implementation of new hygiene technologies by large hotel chains (e.g., Hilton and Marriott), which would have otherwise taken years to install due to bureaucracy, such as the use of ultraviolet light and electrostatics. Revolutionary technologies that minimize social contact (e.g., self-service kiosks) have also been implemented in a timely manner. These implementations may not only lead to higher

cleanliness and better social distancing practices, and therefore, higher guest satisfaction, but also to better booking rates when marketed and communicated correctly.

5.2 Theoretical Implications

This study makes three important contributions to the literature. First, it offers an up-to-date framework for managers to formulate recommendations aimed at avoiding the loss of customer base, similar to the approach taken by Bakar and Rosbi (2020), who explored strategies to prevent demand deterioration in the hospitality industry. Second, it provides researchers with an overview of how TC impacts hotel productivity over time in various geographic regions in the US. Finally, it offers empirical support for fundamental enhancements achievable through technological innovations.

These results can be used in conjunction with the scenario-based modelling introduced by Štumpf et al. (2021) to develop theoretical strategies. Secondly, this paper contributes to the literature comparing the current pandemic to previous crisis situations. In line with the findings of Gössling et al. (2021), this paper also concludes that the pandemic does not appear to have a long-lasting effect on the industry. Third, the ideas proposed in this study are valuable additions to the literature on productivity development in the hotel sector during the pandemic, emphasizing the significance of technological improvements, similar to the work of Scholz et al. (2022), who introduce technology supporting green initiatives.

5.3 Limitations and Future Research

As with other scientific studies, this study has some limitations. First, the analysis was only conducted in the United States. Despite its undisputed importance, for the sake of generalizability, analysis should be extended to other geographical regions in the scope of future research. Second, only secondary financial data were obtained, which do not reflect the intangible characteristics of the hotels. Hence, the author recommends complementing the use of tangible data by intangible measurements, especially in areas which have severely been affected by the pandemic. In numerous regions, the pandemic has induced socio-economic changes in various fields, e.g. the already vulnerable labor market and thus where the improvement in productivity does not only result from revitalizing guest demand. Finally, due to the cumulative nature of MPI, patterns and sources of productivity change may be concealed, while the non-parametric nature of the DEA method renders this framework vulnerable to sample assumptions (Tzeremes, 2021).

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AUTHOR'S ADDRESS

Szilvia Vanessza Schalk-Nador, Faculty of Business and Economics, Mendel University in Brno, Brno, Zemědělská 1, 613 00 Brno, Czech Republic, e-mail: xnador@mendelu.cz, ORCID: 0000-0002-5449-8196

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