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Predicting leadership emergence in global virtual teams

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A B S T R A C T
Objective: This study examines the individual factors that predict whether individuals will emerge as leaders in global virtual teams, which often lack a more formal leadership structure.
Research Design & Methods: We focus on emotional intelligence (EQ) and cultural intelligence (CQ) as two contemporary concepts that are of key relevance to leadership success. Building on socioanalytic theory, we hypothesize that individuals with higher levels of EQ and CQ have a higher probability of emerging as team leaders. We test the hypotheses on a sample of 415 teams comprised of 1 102 individuals who participated in a virtual international collaboration project. Using structural equation modeling, the results reveal that individuals with higher CQ were more likely to emerge as leaders.
Findings: Our findings did not support the relevance of EQ. In addition, individual factors such as English proficiency, a higher age, and a lower power distance were also associated with leadership emergence.
Implications & Recommendations: The study identified the gap in the literature regarding EQ and CQ in the context of leadership emergence. The results demonstrate that individuals with high CQ and high EQ that may have beneficial effects on the team and its outcomes do not automatically emerge as team leaders. We recommend that managers carefully consider which projects and tasks they will leave the leadership structure to emerge more informally.
Contribution & Value Added: The key contribution and value added of this study is the investigation of the role of CQ and EQ with leadership emergence in global virtual teams (GVT), through the creation of a leadership emergence model building on socio-analytic theory.

INTRODUCTION

In light of growing internationalization and continuous technological development, organizations have steadily increased the use of global virtual teams (GVTs) (Taras *et al.*, 2019). A recent survey revealed that up to 87% of white-collar workers in OECD countries at least occasionally work in GVTs (CultureWizard, 2018). As the COVID-19 pandemic imposed restrictions on international travel and many companies shifted to telework, the reliance on GVTs is likely to increase further (Donthu & Gustafsson, 2020).

Jarvenpaa and Leidner (1999) defined GVTs as workgroups that are "temporary, culturally diverse, geographically dispersed, and electronically communicating" (p. 792). For GVTs to be successful and operational, effective leaders are crucial (Lisak & Erez, 2015). Effective leaders have the ability to influence, motivate, and enable others to contribute toward the success of the organization and its members (House, Javidan, Hanges, & Dorfman, 2002). The right leadership brings positive

outcomes to the team and, ultimately, the organization. Leaders facilitate trust, instill the right structures and processes, and involve multiple resources and cultures in temporal, geographical, and complex cultural situations (Park, Jeong, Jang, Yoon, & Lim, 2018, p. 96).

Previous research has identified what influences successful leadership behavior in teams that are diverse and international: among others, the leader's individual motivation is important (Barbuto, 2005), and the leader's intellectual capability, that is, different forms of intelligence, influence leadership effectiveness (Rockstuhl, Seiler, Ang, Van Dyne, & Annen, 2011). Following Gardner (1992) and Sternberg (1999), researchers have argued that instead of considering intelligence in a single form (like "IQ"), one should also consider the social intelligences: these are separate intelligences for emotions and culture, each respectively termed "emotional intelligence" (EQ) and "cultural intelligence" (CQ).

EQ is the ability to assess the emotional aspects of the individual, including empathy towards oneself and others (Wong & Law, 2002). Individuals who have higher EQ will understand the emotions of their team members better, which is beneficial to the team outcomes. CQ is the capability to effectively address culturally diverse settings (Ang *et al.*, 2007; Earley & Ang, 2003), through cognition, metacognition, motivation, and behavior. CQ is found to have a positive association with leadership effectiveness in international workgroups (Groves & Feyerherm, 2011; Offermann & Phan, 2002; Richter, Martin, Hansen, Taras, & Alon, 2021; Yari, Lankut, Alon, & Richter, 2020); EQ is found to have a positive association with leadership effectiveness (Kerr, Garvin, Heaton, & Boyle, 2006). Hence, research supported what Alon and Higgins (2005) conceptualized, namely that a global leader should have a combination of analytical (general) intelligence, EQ and CQ to be effective.

In many GVTs, leaders are not appointed or elected, but emerge. Hence, there often is no formal process that appoints individuals possessing effective leadership skills, such as CQ and EQ as leaders, and research indicates that in some groups, individuals emerge as leaders who may be less effective than others (e.g., Judge, Bono, Ilies, & Gerhardt, 2002; Lanaj & Hollenbeck, 2014). In groups that lack a pre-defined hierarchical or governance structure, leadership emerges because individuals become influential in the perception of followers or are perceived as leaderlike by others (Hogan, Curphy, & Hogan, 1994). Acton, Foti, Lord, and Gladfelter (2019) define leadership emergence "as the multilevel interactional process driven by deep-level cognitive and perceptual processes of group members that form a collective patterning of leader and follower interactions over time" (p. 146). Past research showed a tendency to consider formal team leadership structures, despite the fact that leadership is often more informally distributed within teams, especially in contemporary global virtual settings (Morgeson, DeRue, & Karam, 2010). Hence, there is a need to further understand informal leadership emergence, especially in GVTs (with their more complex cross-cultural and technology-supported settings) as compared to face-to-face settings (Avolio, Sosik, Kahai, & Baker, 2014).

The key contribution of this study is to investigate the role of CQ and EQ with leadership emergence in GVTs. Thereby, we respond to the call by Judge, Colbert, and Ilies (2004) to investigate other forms of intelligence to understand leadership emergence. In addition, we thereby will investigate whether the self-selection mechanism in GVT without a formal leadership structure will result in informal leadership structures that are effective or create leaders that have the right skills. For this purpose, we create a leadership emergence model building on socioanalytic theory (Hogan & Blickle, 2018) and theorize how EQ and CQ motivate the individual to have the team members get along, get ahead, and find meaning, and therewith emerge as a leader. We test our hypotheses on a sample of 415 teams comprised of 1 102 individuals who participated in a virtual international collaboration project using structural equation modeling.

LITERATURE REVIEW AND HYPOTHESES DEVELOPMENT

We build on socio-analytic theory to develop a model that associates EQ and CQ with leadership emergence. From this perspective, three motives and behaviors are key in the process of leadership emergence: Getting along (communion), that is the behavior that achieves the approval of others, strengthens cooperation, and serves to build and maintain relationships. Getting ahead (agency), that is the behavior that produces results and advances members within the group and the group within its competition.

Lastly, these findings mean, that the behavior that produces stable, predictable, and meaningful social interactions in everyday living (Hogan & Blickle, 2018; Hogan & Holland, 2003).

By using socioanalytic theory, we hypothesize the following that individuals with high EQ and CQ may be more motivated and able to get along, get ahead or find meaning in their teams and therewith emerge as leaders.

Emotional Intelligence (EQ)

We follow Salovey and Mayer (1990), who defined EQ as "the ability to monitor one's own and others' feelings and emotions, to discriminate among them and to use this information to guide one's thinking and actions" (p. 189). EQ involves four dimensions: Regulation of emotion (ROE) that regards the ability to regulate emotions; self-emotional appraisal (SEA) that concerns the ability to understand deep emotions and express these freely; others' emotional appraisal (OEA) that relates to the ability to observe and understand emotions of other people; and, use of emotion (UOE) that is the ability to use emotions on meaningful activities and performance (Wong & Law, 2002).

A majority of studies indicate that emotionally intelligent individuals are more likely to emerge as leaders (see, for instance, the review in Walter, Cole, & Humphrey, 2011). Intuitively, EQ is relevant to leadership, as "leadership is an emotion-laden process, both from a leader and follower perspective" (George, 2000, p. 1046).

Using socioanalytic theory, we associate EQ with leader emergence (Hogan & Blickle, 2018) and hypothesize that individuals with higher EQ are more likely to emerge as leaders in GVT: First, individuals with higher EQ better understand others' emotions and have a better knowledge of the group members' attitudes, goals, and interests and needs enabling better relationships between team members. Moreover, they can better manage emotions within groups, which improves cooperation and facilitates establishing social relationships. Hence, individuals with a higher EQ should get along better with their group members and therewith should have a higher probability of emerging as a leader. Second, individuals with higher EQ can process information better before deciding on tasks, create ideas and make suggestions in the team, and demonstrate result-oriented behavior. They make use of their emotions and direct them toward group activities and tasks, and use creative behavior to motivate the team to get ahead (Salovey & Mayer, 1990; Cote, Lopes, Salovey, & Miners, 2010). They consider an emotional strategy that fits the needs of the group members to achieve higher performance. Hence, individuals with a higher EQ are better at getting the team ahead and therewith show a higher probability of emerging as a leader. Third, individuals with higher EQ would find meaning by creating emotional strategies to improve and create social interactions that foster emotional regulation growth in the team (Wong & Law, 2002). They find meaning through positive thinking, expressing emotions to themselves and group members that create stable within-group relationships (Salovey & Mayer, 1990). They find meaning in emerging as a leader when they identify a problem and offer a solution (Salovey & Mayer, 1990). Hence, individuals with a higher EQ are better at finding meaning within the team and herewith show a higher probability of emerging as a leader.

In summary, we expect that individuals with higher EQ are more likely to emerge as a leader:

H1: The higher the EQ of a team member, the higher the probability that the individual will emerge as a leader in the team.

Cultural Intelligence (CQ)

While there are several definitions of CQ in international business and management (Andresen & Bergdolt, 2017; Yari *et al.*, 2020), We follow Ang and Van Dyne (2008) and Earley and Ang (2003) and define CQ as the capability to succeed in complex cross-cultural environments through knowledge or cognition, motivation, and behaviors. The cross-cultural context of GVT poses cross-cultural challenges to teamwork. Groups that are composed of members with different cultural backgrounds are faced with different perceptions of the rules of interaction or meaning that is attributed to situations and behaviors. Hence, to be perceived as leaders, individuals need to be able to navigate this cross-cultural context (Marinova, Moon, & Kamdar, 2013).

CQ involves four dimensions: Metacognitive CQ concerns the mental capability to acquire and understand cultural knowledge. Cognitive CQ regards general knowledge and knowledge structures about culture. Motivational CQ describes the capability to focus energy on learning about and functioning in different intercultural situations. Lastly, behavioral CQ represents the capability to be flexible in the repertoire of verbal and non-verbal behavior in different cultural encounters (Ang & Van Dyne, 2008; Earley & Ang, 2003). Previous research examined the relationship of CQ with leadership (Ang *et al.*, 2007; Groves & Feyerherm, 2011; Rockstuhl *et al.*, 2011; Rockstuhl & Van Dyne, 2018) and demonstrated positive implications. There are also a number of studies that find that CQ is associated with outcomes such as job performance (Ang *et al.*, 2007), negotiation (Imai & Gelfand, 2010), and expatriate adjustment (Malek & Budhwar, 2013).

Using socioanalytic theory to associate CQ with leader emergence (Hogan & Blickle, 2018), we hypothesize that individuals with higher CQ are more likely to emerge as leaders in GVT, because they demonstrate the relevant capabilities to get along, get ahead and find meaning: Individuals with higher cognitive and metacognitive CQ have a better knowledge of cultural norms and values that helps them to map cross-cultural situations. They are sensitive to potential differences among group members (cognitive CQ) and reflective of cultural behaviors during the group work (metacognitive CQ) (Lisak & Erez, 2015). They know when and how to apply cross-cultural knowledge (metacognitive CQ) (Ang *et al.*, 2007), which enables them to get along better with their team members. Moreover, individuals with higher cognitive CQ have a better understanding of differences in role expectations and culturally-bounded habits and thinking (Van Dyne *et al.*, 2012). In addition, their metacognitive CQ allows them to plan ahead and check whether chosen strategies contribute to getting the team ahead (Van Dyne *et al.*, 2012). Overall cognitive and metacognitive CQ therewith contribute to getting ahead motives in the team. Finally, because culture defines the rules which provide social interactions with meaning (Hogan & Bond, 2009), cognitive and metacognitive CQ are relevant to understand how to provide the relevant meaning in culturally diverse GVT; they contribute to "insider understanding" (Van Dyne *et al.*, 2012, p. 302), help in producing cultural interactions that become meaningful, and are less affected by stereotypes (Triandis, 2006). Hence, they contribute to finding meaning motives in the team.

Individuals with higher motivational CQ have an increased drive to enjoy cross-cultural interactions and maintain relationships across cultures, and they drive to learn and function in different cultural situations (Ang *et al.*, 2007). Individuals with higher motivational CQ drive to enable stronger cooperation, maintenance of the relationship, and solving conflicts in the groups (Lisak & Erez, 2015), which enables the group to get along and reach a higher communion. Individuals high in motivational CQ have high confidence or self-efficacy belief in mastering the challenges attributed to GVTs and accomplishing a certain level of performance in culturally diverse situations; Due to their higher self-efficacy, they strive for higher goals and are better able to manage the stressors in cross-cultural environments (Van Dyne *et al.*, 2012). Finally, motivational CQ is relevant to understand how to provide the relevant meaning in culturally diverse GVTs; it includes the intrinsic interest and satisfaction obtained from cultural interactions and excitement of working with culturally different people, and a novel interest to work and engage in culturally diverse teams (Van Dyne *et al.*, 2012).

Individuals with higher behavioral CQ create more adaptations to the verbal and nonverbal behaviors to meet the expectation of others, improving communion and enabling others to perceive an individual as a leader. Individuals also need behavioral CQ to decrease misunderstandings and increase team members' task performance to get ahead (Ang *et al.*, 2007). Higher behavioral CQ also increases the effective intercultural interactions through verbal, non-verbal, and speech-acts behaviors that produce results for both members and the team (Van Dyne *et al.*, 2012). Finally, behavioral CQ is relevant to understand how to provide the relevant meaning in culturally diverse GVT; it enables greater flexibility for effective communication, greater respect for cultural differences, and a greater understanding of communication cues and social interactions. Hence, behavioral CQ contributes to greater respect for the culturally-different others (Van Dyne *et al.*, 2012).

In summary, we expect that individuals with higher CQ are more likely to emerge as a leader:

H2: The higher the CQ among an individual team member, the higher the probability that the individual will emerge as a leader in the team.

RESEARCH METHODOLOGY

Sample

To test our hypotheses, we use data from a large-scale virtual international collaboration project. Throughout the project, participants needed to develop solutions to real-life business challenges, including, for instance, market entry plan development and product design. The project had a duration of nine weeks, during which participants were put into virtual teams of four to eight members from different countries. Our final sample comprised 1 102 participants from more than 50 countries across 415 teams for whom we had complete data.

Measures

The *leadership emergence* was assessed through participants' peer evaluation of a member's role in the team ("This person's role on the team?"). A score of 4 would indicate that the whole team would anonymously see the member as a formal leader, 3 would indicate an informal leader, 2 would indicate a follower, and 1 would indicate no participating behavior. An average from all the peer evaluations of each team member was calculated at the end of the project.

We measured *emotional intelligence* and its dimensions using the instrument by Wong and Law (2002); that is, we used a seven-point agreement scale on in total of 16 items (i.e., four items to operationalize each dimension of EQ; SEA, OEA, UOE and ROE).

We measured *cultural intelligence* using the (CQS) scale by Ang *et al.* (2007). We measured metacognitive CQ with three items (as one item of the original scale was not included in the survey), cognitive CQ with six items, motivational CQ with five items, and behavioral CQ with five items using a five-point agreement scale.

We *controlled for* age, gender (coded 1 for males), team size (total number of members in the team) and cultural values, international experience as well as English language proficiency. We used the scale developed by Yoo, Donthu, and Lenartowicz (2011) to measure the four key dimensions of the Hofstede framework (20 items): Masculinity (four items), collectivism vs. individualism (six items), power distance (five items), and uncertainty avoidance (five items) on a five-point agreement scale. International experience was reported as the total time spent abroad studying or for tourism (from "0-4 weeks" to "4 or more years"). English proficiency was operationalized as self-evaluations of participants' proficiency in listening, reading, speaking, and writing English (from 0, "very poor", to 10, "excellent").

Analysis Technique and Approach

We use partial least squares structural equation modeling (PLS-SEM) which has become a standard analysis technique to investigate causal-predictive relationships in path models with latent variables (Hair, Risher, Sarstedt, & Ringle, 2019). PLS-SEM benefits predictive and exploratory purposes because the extraction of latent variable scores, in conjunction with the explanation of a large percentage of the variance in the indicator variables, are useful for accurately predicting individuals' scores on the latent variables. Thus, PLS-SEM has become a useful method for predictive modeling (Shmueli *et al.*, 2019). We use the SmartPLS 3 software to run the PLS-SEM models (Ringle, Wende, & Becker, 2015).

For both CQ and EQ, there are different approaches to empirically use the construct that range from using the individual dimensions to the aggregate construct or combinations of the two (see Rockstuhl & Van Dyne, 2018; Schlaegel, Richter, & Taras, 2021). We implement both the individual dimensions (the four-factor model) as well as the overall constructs (the single-factor model) and test two different types of models accordingly above and beyond a control model (Model 1): Model 2 uses the four-factor structures of EQ and CQ, and Model 3 uses single-factor constructs of EQ and CQ.
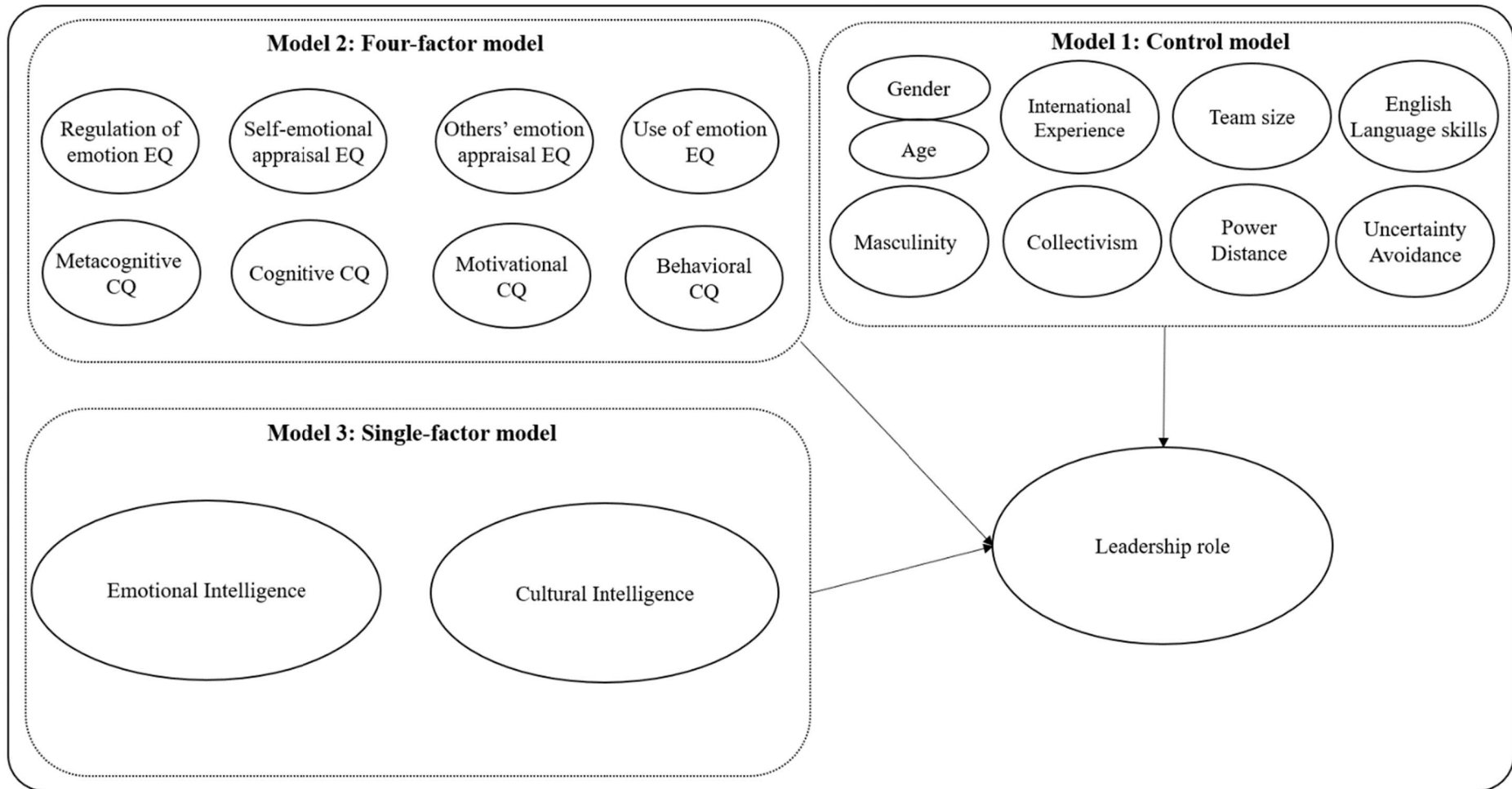
Figure 1. Conceptual model
Source: own elaboration.

RESULTS AND DISCUSSION

The Measurement Models

The means, standard deviations (S.D.), and correlations appear in Table 1.

In the first step, we evaluated the measurement models along traditional guidelines (Hair *et al.*, 2019; Hair Jr., Hult, Ringle, & Sarstedt, 2016). In addition to single items (age, gender, team size, leadership role), we used reflective measurement models for EQ, CQ, and cultural values, and a formative measurement model for international experience (comprised of two indicators that each capture a specific aspect of the construct which fits the idea of a formative measurement model, e.g., Fornell & Bookstein, 1982).

For the reflective measurement models, nearly all of the measurement items loaded above the required threshold (> 0.708), and those items failing the initial threshold received further testing and were kept whenever their removal did not improve internal consistency reliability. This led to two items to be dropped from the cultural values masculinity measure, one item from others' emotional appraisal EQ, and two items from self-emotional appraisal EQ. Our final measurement models demonstrate internal consistency reliability, convergent validity (AVE > 0.50), and discriminant validity evaluated along the heterotrait-monotrait (HTMT) criterion (see appendix for results).

For the formative measurement model, international experience, the results show that the weights are not significant for study abroad ($p = 0.079$) or tourism ($p = 0.106$), but the loadings are significant ($p = 0.016$, $p = 0.023$) and above the minimum thresholds to keep items (see appendix for results). Finally, there are no issues of multicollinearity in our model.

Hypothesis Testing

We assess the structural model using the standard assessment criteria in Hair *et al.* (2019) as provided in Table 2: The control model (Model 1) explains 7.2 % of the variance in a leadership role ($R^2 = 0.072$, $R^2_{adjusted} = 0.061$), the four-factor model (Model 2) explains 10.7 % ($R^2 = 0.107$, $R^2_{adjusted} = 0.080$); and the single-factor model (Model 3) explains 9.5 % ($R^2 = 0.095$, $R^2_{adjusted} = 0.078$). These R-squared sizes can be considered weak, but given the context and nature of this study, the level of explanatory power fits to levels achieved in other, comparable studies (e.g., see Rockstuhl & Van Dyne, 2018). Both Model 2 and Model 3 show more explanatory power above and beyond the control model ($\Delta R^2_{four-factor} = 0.035$, $\Delta R^2_{single-factor} = 0.023$). Finally, the results indicate that the models show predictive relevance ($Q^2 > 0$) that we further assessed by means of the model's out-of-sample predictive power using the PLSpredict procedure (Shmueli, Ray, Estrada, & Chatla, 2016).

Table 3 provides the results of the PLSpredict procedure. We compare the root mean squared error (RMSE) and the mean absolute error (MAE) to the linear model (LM) benchmark and compare the prediction errors (Hair *et al.*, 2019). The PLS-SEM predictions' RMSE values are smaller than those of the LM benchmark for leadership roles ($\Delta four\text{-}factor_{RMSE} = -0.040$, $\Delta single\text{-}factor_{RMSE} = -0.044$). The predictions' MAE values are smaller than those of the LM benchmark for leadership roles ($\Delta four\text{-}factor_{MAE} = -0.029$, $\Delta single\text{-}factor_{MAE} = -0.034$). This comparison shows that the models have predictive power (Hair *et al.*, 2019).

We posited that the four-factor EQ and the four-factor CQ would predict the emergence of leadership and tested this in our Model 2. The results show that regulation of emotion ($\beta = -0.078$; $p > 0.05$), self-emotion appraisal ($\beta = 0.047$; $p > 0.05$), others' emotion appraisal ($\beta = -0.004$; $p > 0.05$), and use of emotion ($\beta = -0.031$; $p > 0.05$) were not significantly associated with leadership role. Hence, Hypothesis 1 is not supported. Metacognitive CQ was positively associated with leadership role ($\beta = 0.117$; $p < 0.05$), but cognitive CQ ($\beta = 0.028$; $p > 0.05$), motivational CQ ($\beta = -0.073$; $p > 0.05$) and behavioral CQ ($\beta = 0.068$; $p > 0.05$) were not. Hence, Hypothesis 2 is only partially supported. Age ($\beta = 0.099$; $p < 0.05$), English proficiency ($\beta = 0.112$; $p < 0.05$), team size ($\beta = -0.174$; $p < 0.05$), and power distance ($\beta = -0.106$; $p < 0.05$) were also significantly associated with leadership role. Gender ($\beta = -0.059$; $p > 0.05$), international experience ($\beta = 0.076$; $p > 0.05$), masculinity ($\beta = 0.068$; $p > 0.05$), collectivism ($\beta = 0.074$; $p > 0.05$) and uncertainty avoidance ($\beta = -0.026$; $p > 0.05$) were not significantly associated with leadership role.

Table 1. Correlations among model variables

Variable	Mean	S.D.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1.Age	2.20	1.12	–																
2.CQ Cogn	3.26	0.98	-0.06	–															
3.CQ Behav	3.68	0.94	0.04	0.43**	–														
4.CQ Motiv	4.15	0.84	-0.01	0.39**	0.46**	–													
5.CQ M.cogn	4.09	0.83	0.02	0.33**	0.47**	0.62**	–												
6.EQ OEA	4.08	0.74	-0.01	0.16*	0.23**	0.18**	0.14**	–											
7.EQ SEA	4.13	0.76	0.09*	0.10*	0.22**	0.29**	0.27**	0.28**	–										
8.EQ UOE	4.23	0.73	0.07*	0.20**	0.27**	0.30**	0.32**	0.28**	0.46**	–									
9.EQ ROE	3.98	0.85	0.10*	0.20**	0.20**	0.23**	0.20**	0.27**	0.43**	0.42**	–								
10.Gender	0.49	0.5	0.03	0.02	-0.04	-0.02	0.01	-0.06	0.06	-0.02	0.11*	–							
11.Int. exp.	5.05	2.33	0.14*	0.08	0.01	0.04	0.06	-0.01	0.08*	0.11*	0.11*	0.10*	–						
12.Eng. prf.	9.33	0.77	0.09*	-0.01	0.11**	0.14*	0.14**	0.15*	0.18**	0.17**	0.08	0.08*	0.07	–					
13.Collect.	3.54	1.02	0.00	0.11*	0.12*	0.22*	0.16*	0.03	0.05	0.03	-0.04	-0.04	0.06	0.16**	–				
14.Masc.	2.13	1.12	0.04	-0.03	-0.04	-0.10*	-0.11*	-0.03	-0.09	-0.08	-0.01	0.20**	0.101*	-0.06	0.02	–			
15.PD	1.83	1.16	-0.01	0.02	-0.08*	-0.20*	-0.14*	-0.03	-0.08	-0.10	0.00	0.17**	0.09	-0.21**	-0.11*	0.44**	–		
16.UA	4.05	0.88	0.08	0.09	00.22**	0.24*	00.24**	0.08	00.19**	0.19*	0.06	-0.17**	0.10*	0.04	0.06	-0.05	-0.11	–	
17.Team size	5.90	0.76	0.09*	0.06	-0.02	0.05	0.00	-0.08*	0.02	0.04	0.07	0.05	0.16**	-0.06	-0.18**	-0.00	0.04	0.03	–
18.Leader Role	2.19	1.01	00.10**	0.04	0.12**	0.06	00.13**	0.03	0.05	0.03	-0.04	-0.04	0.06	00.16**	0.07	0.02	-0.11	0.10	-0.18**

N = 1,102. Age: 1 = 17-20, 2 = 21-24, 3 = 25-28, 4 = 29 - 32, 5 = 33 - 36, 6 = 37-40, 7 = 41 - 44, 8 = 45-48, 9 = 60+; Gender: 1 = Male, 2 = Female; * p<0.05; ** p<0.01.

Source: own calculation based on the sample (n = 1.102).

Table 2. Structural model results

Construct	Model 1				Model 2				Model 3			
	Path β (p-value)	t-value	95% Conf. interv	Sig.[a]	Path β (p-value)	t-value	95% Conf. interv	Sig.[a]	Path β (p-value)	t-value	95% Conf. interv	Sig.[a]
Gender	-0.036 (0.161)	0.991	[-0.092; 0.029]	No	-0.059 (0.08)	1.406	[-0.118, 0.019]	No	-0.059 (0.075)	1.439	[-0.117; 0.017]	No
Age	0.065 (0.034)	1.82	[0.001; 0.118]	Yes	0.099 (0.007)	2.496	[0.032; 0.165]	Yes	0.097 (0.007)	2.477	[0.033; 0.163]	Yes
International experience	0.077 (0.062)	1.541	[-0.065; 0.131]	No	0.076 (0.048)	1.67	[-0.013; 0.146]	No	0.072 (0.055)	1.602	[-0.014; 0.140]	No
English proficiency	0.141 (0.000)	4.132	[0.081; 0.194]	Yes	0.112 (0.002)	2.954	[0.046; 0.170]	Yes	0.108 (0.002)	2.857	[0.041; 0.164]	Yes
Team Size	-0.125 (0.000)	3.509	[-0.186; -0.070]	Yes	-0.174 (0.000)	4.623	[-0.238; -0.114]	Yes	-0.182 (0.000)	4.849	[-0.236; -0.113]	Yes
Masculinity	0.080 (0.071)	1.471	[-0.033; 0.151]	No	0.068 (0.142)	1.072	[-0.035; 0.172]	No	0.074 (0.122)	1.167	[-0.036; 0.171]	No
Collectivism	0.058 (0.134)	1.109	[-0.143; 0,089]	No	0.074 (0.120)	1.177	[-0.067; 0.161]	No	0.057 (0.182)	0.909	[-0.080; 0.148]	No
Power Distance	-0.094 (0.016)	2.147	[-0.130; 0.136]	Yes	-0.106 (0.022)	2.02	[-0.188; -0.041]	Yes	-0.102 (0.017)	2.123	[-0.181; -0.046]	Yes
Uncertainty Avoidance	0.040 (0.324)	0.458	[-0.154; 0.121]	No	-0.026 (0.344)	0.401	[-0.154; 0.121]	No	-0.020 (0.321)	0.321	[-0.140; 0.081]	No
EQ ROE					-0.078 (0.121)	1.172	[-0.173; 0.055]	No				
EQ SEA					0.047 (0.170)	0.953	[-0.047; 0.116]	No				
EQ OEA					-0.004 (0.472)	0.071	[-0.102; 0.086]	No				
EQ UOE					-0.031 (0.292)	0.547	[-0.106; 0.078]	No				
CQ M.cogn					0.117 (0.017)	2.126	[0.014; 0.194]	Yes				
CQ Cogn					0.028 (0.361)	0.357	[-0.121; 0.119]	No				
CQ Motiv					-0.073 (0.201)	0.837	[-0.212; 0.081]	No				
CQ Behav					0.068 (0.079)	0.357	[-0.008; 0.150]	No				
EQ									0.002 (0.492)	0.021	[-0.173; 0.129]	No
CQ									0.103 (0.033)	1.838	[0.059; 0.191]	Yes
R^2	0.072				0.107				0.095			
R^2 adjusted	0.061				0.08				0.078			
Q^2					0.043				0.042			

Note: N = 587. Significance testing in the PLS-SEM models is performed with 5,000 bootstrap samples. [a] To assess signifi-cance, we refer to the 95% BCa-confidence intervals given above.
Source: own calculation based on the sample (n = 587).

Table 3. PLSpredict leadership role prediction summary

Endogenous construct indicators	PLS-SEM	MAE	$Q^2_{predict}$	LM	MAE	PLS-SEM – LM	
	RMSE			RMSE		RMSE	MAE
Leadership role (control)	0.989	0.847	0.037	0.996	0.847	-0.007	0
Leadership role (four-factor)	0.981	0.832	0.031	1.021	0.861	-0.040	-0.029
Leadership role (Overall)	0.979	0.829	0.036	1.023	0.863	-0.044	-0.034

Source: own calculation based on PLSpredict procedure.

In the single-factor model (Model 3), we tested whether the single-factor EQ and single-factor CQ would predict leadership emergence. The results show that the single factor-EQ (β = 0.002; p > 0.05) was not significantly associated with leadership role, which again does not provide support to our Hypothesis 1. The single-factor CQ (β = 0.103; p < 0.05) was positively associated with leadership role, lending support to our Hypothesis 2. Age (β = 0.097; p < 0.05), English proficiency (β = 0.108; p < 0.05), team size (β = -0.182; p < 0.05), and power distance (β = -0.102; p < 0.05) were also significantly associated with leadership role. Gender (β = -0.059; p > 0.05), international experience (β = 0.072; p > 0.05), masculinity (β = 0.074; p > 0.05), collectivism (β = 0.057; p > 0.05) and uncertainty avoidance (β = -0.020; p > 0.05) were not significantly associated with leadership role.

We also assessed the relative impact of predictive relevance by the blindfolding procedure, also referred to as *the effect size q²* (Hair Jr. *et al.*, 2016), and values above 0.02 are meaningful. Only English proficiency (q^2 = 0.017), age (q^2 = 0.020) and team-size (q^2 = 0.034) were found to have predictive relevance for leadership role.

CONCLUSIONS

Overview of Findings

The results of our study indicated that EQ did not significantly explain nor significantly predict the emergence of a leadership role – neither when analyzed using a four-factor nor a single-factor operationalization (lending no support to Hypothesis 1). Our findings indicated that CQ matters to leadership emergence in GVT, with the single-factor model demonstrating a significant association with a leadership role (lending support to Hypothesis 2). Testing the four-factor model, the results demonstrated that only metacognitive CQ was associated with the emergence of leadership (lending partial support to Hypothesis 2).

Finally, we found that English proficiency and age were positively associated, while team size and power distance were negatively associated with leadership role across all models. Additionally, English proficiency, age, and team size were found to have predictive relevance for leadership role.

Theoretical Implications

We contributed to the existing body of leadership literature by further understanding the association of EQ and CQ with leadership emergence. While there were several studies on the association of EQ with leadership emergence, there are almost no studies that research CQ in the context of leadership emergence (exceptions are Lisak & Erez, 2015). Past research indicated that EQ and CQ matter to the success of leaders, and there are good theoretical arguments that both forms of intelligence are also relevant to leadership emergence. Building on socioanalytic theory (Hogan & Blickle, 2018), we outlined that individuals may be perceived as stronger in their motivation to get along, get ahead, or find meaning in their teams when their EQ and CQ are higher; and this is theorized to contribute to the emergence of leadership.

A reason for the difference in the association between EQ and CQ with leadership emergence might be that members who work in GVT may first and foremost encounter cultural rather than emotional challenges. GVT functions using virtual collaboration for a short duration of time, making team members have more cultural-laden processes instead of emotion-laden processes. In theory, individ-

uals with higher EQ have increased emotional perception, emotional processing, and emotional reflection for handling team members' emotion-laden processes. While of relevance to the success of leaders, this seems to be less relevant when it comes to predicting leadership emergence in a GVT setting. Our results support similar findings where CQ mattered more than EQ in cross-border settings (i.e., EQ matters more for domestic leadership, see Rockstuhl *et al.*, 2011).

Our findings are in general consistent with what Lisak and Erez (2015) found: individuals that portray high global leadership characteristics (i.e., CQ) are perceived by their team members as more worthy to the global work context, hence appointed by their team members as the team leader. Still, the explanatory power of the model remains low, and an assessment of the predictive relevance of CQ showed that the practical relevance of CQ and metacognitive CQ in predicting the emergence of leaders is not given. Hence, in the multicultural non-face-to-face setting, CQ and especially metacognitive CQ may enable individuals to reflect on their behavior, plan ahead, and find meaning through cultural interactions, but these abilities, only to a marginal extent, translate into leadership emergence. In contrast, skills and factors that we controlled for demonstrated more relevance: that is, better language skills and being older.

Our study suggests that language skills and demographic factors such as age are more important than EQ and CQ to the emergence of leadership. That is, surface-level characteristics seem to play a stronger role in the emergence of leadership in GVT. The appropriate language skills can address team conflict, aid performance-based tasks, and foster social interactions right away. Moreover, GVT members can perceive the potential leader's age as an indicator of experience and skills. While deeper-level factors, such as CQ and EQ, may matter to team-processes, they seem to not contribute as strongly as surface-level factors to the emergence of leadership. These findings offer two first starting points for future research: First, researchers may test the underlying mechanisms outlined in socioanalytic theory in the context of leadership emergence, ideally by developing research designs that enable direct measurement of the facets of getting along, getting ahead, and finding meaning (see Richter, Schlaegel, Taras, Alon & Bird, 2023). Second, researchers may further explore the role of deep-level versus surface-level factors in the context of leadership emergence in GVT.

Finally, the low predictive relevance of EQ and CQ is somewhat surprising, and we call for future research that further analyses their role in leadership emergence. Authors argue that it may be fruitful to look at a combination of, or configurations of, traits and competencies (EQ and CQ), instead of considering these factors separately (Bergman & Magnusson, 1997). This may involve – among others – the exploration of individual EQ and CQ profiles. That is, specific patterns of EQ and CQ strengths among an individual that matter to becoming a leader. In addition, it may be that it is not about an ever higher EQ and ever higher CQ to emerge as a leader, but about a necessary minimum level that needs to be there as a must-have factor for leadership to emerge, which may call for a combination of sufficiency and necessity logic in developing research designs (*e.g.*, Richter, Schubring, Hauff, Ringle, & Sarstedt, 2020).

Practical Implications for HRM

Our study demonstrates that individuals with high CQ and high EQ that may have beneficial effects on the team and its outcomes do not automatically emerge as team leaders. That is, if the management lets the team decide who should lead, the leadership structure will most probably differ considerably from the structure that a manager would actively choose for the team to perform best.

A leader emerges because the individual becomes influential in the view of followers and is perceived as more leaderlike (Hogan *et al.*, 1994), and in GVTs, this is most dominantly the case for individuals with strong language skills and higher age. To a lesser extent, this is induced by CQ and a low power distance attitude of individuals. Hence, leadership structures may emerge that lack relevant individual factors that have a proven record of being positively associated with team outcomes, such as satisfaction and performance, and instead have more of relevant surface-level characteristics (*i.e.*, English proficiency and age).

We advise managers to carefully consider which projects and tasks they will leave the leadership structure to emerge more informally. A leadership structure that lacks individual factors such as EQ and CQ relevant can potentially reduce performance-results, increase intra-team conflict, hinder

team communication, and induce a mixture of unmet expectations within the team (Jarvenpaa & Leidner, 1999). Even if there are individuals in the team that bring the relevant individual skills, including factors such as age, and language skills, certain cultural value patterns, such as high power distance, may prevent them from emerging as leaders. Hence, for projects of specific and strategic relevance, the management is advised to actively engage in the creation of leadership structures that follow findings from the rich field of leadership success.

Limitations and Future Research

To the best of our knowledge, this is the first study to empirically compare EQ and CQ with leadership emergence in GVTs. This study is not without limitations that should be addressed and can serve as a reference for future directions. First, our study uses ability-based self-report/peer-evaluation measures and not ability-based judgment tests of EQ and CQ. Both instruments of EQ and CQ are validated and reliable, but self-report/peer-evaluation measures can be biased by the individuals' beliefs of their emotional and cultural abilities rather than their actual abilities. Ability-based judgment tests of EQ (see MSCEIT by Mayer, Salovey, & Caruso, 2004) and CQ (see situational judgment tests by Rockstuhl, Ang, Ng, Lievens, & Van Dyne, 2015) would have a lower risk of fake or socially desirable responses.

Second, our leadership emergence model is based on individual predictions of the characteristics, though there may be arguments that it is less about individual characteristics separately but about joint effects or archetypes of individual factors (e.g., Richter *et al.*, 2016; Schlaegel, Richter, & Taras, 2017). We acknowledge that this may be a limitation that was out of the scope of this study and encourage future research to test possible combinations, configurations, or patterns of these characteristics for which procedures such as qualitative comparative analyses or necessary condition analysis could be beneficial avenues (see Dul, 2016; Richter & Hauff, 2022).

Third, we used socioanalytic theory (Hogan & Blickle, 2018) to outline a leadership emergence model using EQ and CQ. Our leadership emergence model suggests individuals are more motivated to get along, get ahead, or find meaning in their teams when their EQ or CQ is higher. However, our study did not test the three motivators to lead directly. Future research should test and use the three motivators to lead (get along, get ahead, and find meaning) with EQ and CQ to further test our theoretical arguments.

Fourth, also personality traits were previously found to be predictors of leadership emergence (Judge, Piccolo, & Kosalka, 2009) that we were unable to incorporate into our model (due to the unavailability of the relevant measures). Future research is encouraged to further compares the relevance of personality traits (e.g., emotional stability, openness to experience, or self-confidence) with the relevance of EQ and CQ in predicting leadership emergence.

Finally, participants in this study were business students (also including MBAs) who developed solutions to real-life business challenges. Other similar studies have also used students that may or may not complete the assignment as partial fulfillment for their course requirements (Lisak & Erez, 2015). The use of student samples has been discouraged by several editorial policies and by scholars in the literature, yet they become appropriate when used to study aspects of human nature and propensity that can explain specific phenomena in an international setting. Any sample of multicultural teams, including students, can undergo fundamental research that looks at underlying processes of human cognition and behavior (Bello, Leung, Radebaugh, Tung, & van Witteloostuijn, 2009). In this study, we use a homogenous sample (business students) to compare the predictive relevance of EQ and CQ above and beyond further predictors, such as cultural values, language skills, and international experience (that we control for). Nonetheless, future research is invited to validate our findings by examining EQ and CQ in fixed, long-term GVT in organizations.

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Conflict of Interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

The data that support the findings of this study are available on request from the corresponding author, ZHM. The data are not publicly available due to information that could compromise the privacy of research participants.

Artificial intelligence prompt engineering as a new digital competence: Analysis of generative AI technologies such as ChatGPT

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A B S T R A C T
Objective: The article aims to offer a thorough examination and comprehension of the challenges and prospects connected with artificial intelligence (AI) prompt engineering. Our research aimed to create a theoretical framework that would highlight optimal approaches in the field of AI prompt engineering.
Research Design & Methods: This research utilized a narrative and critical literature review and established a conceptual framework derived from existing literature taking into account both academic and practitioner sources. This article should be regarded as a conceptual work that emphasizes the best practices in the domain of AI prompt engineering.
Findings: Based on the conducted deep and extensive query of academic and practitioner literature on the subject, as well as professional press and Internet portals, we identified various insights for effective AI prompt engineering. We provide specific prompting strategies.
Implications & Recommendations: The study revealed the profound implications of AI prompt engineering across various domains such as entrepreneurship, art, science, and healthcare. We demonstrated how the effective crafting of prompts can significantly enhance the performance of large language models (LLMs), generating more accurate and contextually relevant results. Our findings offer valuable insights for AI practitioners, researchers, educators, and organizations integrating AI into their operations, emphasizing the need to invest time and resources in prompt engineering. Moreover, we contributed the AI PROMPT framework to the field, providing clear and actionable guidelines for text-to-text prompt engineering.
Contribution & Value Added: The value of this study lies in its comprehensive exploration of AI prompt engineering as a digital competence. By building upon existing research and prior literature, this study aimed to provide a deeper understanding of the intricacies involved in AI prompt engineering and its role as a digital competence.

INTRODUCTION

The artificial intelligence (AI) revolution was propelled by the emergence of unsupervised learning, which enabled models to learn from vast, unstructured datasets (Korzynski, Haenlein, & Rautiainen, 2021). Before 2017, AI focused on narrow tasks through supervised learning, but the introduction of the transformer architecture changed this approach. Models began to identify patterns in data, improving their ability to tackle various tasks. An evolved iteration of OpenAI's Generative Pretrained Transformer (GPT) series, advanced this further by highlighting the potential of prompting models for

a better understanding of user context. This emergent property, in-context learning via prompting, has become a fundamental aspect of modern machine-learning models (Cuofano, 2023). Furthermore, AI generative technologies, such as ChatGPT or Bard, have significantly impacted the business landscape, transforming the way organizations operate, communicate, and innovate (Korzynski, Kozminski, & Baczynska, 2023; Wach *et al.*, 2023). These technologies facilitate more efficient processes, enhance decision-making, and enable the creation of personalized user experiences, all of which contribute to a more human-centric approach in the era of digital transformation (Korzynski *et al.*, 2023).

Robin Li, the co-founder and CEO of the Chinese AI giant Baidu, predicts that in ten years, half of the world's jobs will involve prompt engineering, and those who cannot write prompts will become obsolete (Smith, 2023). Although this statement might be somewhat overstated, prompt engineers will undoubtedly hold an essential position in the realm of artificial intelligence. These professionals will adeptly steer AI models to generate content that aligns with the desired outcome, ensuring that it is not only pertinent but also cohesive and coherent. Some media indicate that currently, a novel type of AI-related occupation is surfacing, offering six-figure incomes without the necessity for a computer engineering degree or advanced coding abilities. As generative artificial intelligence gains prominence, numerous businesses are seeking to employ 'AI prompt engineers' responsible for refining the performance of AI tools to provide more precise and pertinent answers to questions posed by real individuals. Some of these positions can command annual salaries of up to 335 000 USD (Popli, 2023). Prompt engineering provides remarkable benefits for individuals and organizations working with generative AI models. It allows for greater control over the output, as the right prompts can help ensure AI models create the desired content. Additionally, effective prompts contribute to improved accuracy by guiding AI models to generate more relevant and valuable content. Furthermore, prompt engineering can enhance creativity by presenting AI models with new and unique prompts to explore (God, 2023).

At first glance, one might assume that AI prompt engineering is primarily associated with information technology rather than a human-centric discipline. However, in this article, we aim to offer an alternative perspective. Artificial intelligence prompt engineering is a human language-focused practice in which individuals create prompts using unique and separate elements of text, known as distinct tokens. This method is different from 'soft prompting' techniques, which emphasize automatic fine-tuning of inputs for machine learning models (Ghazvininejad, Karpukhin, Gor, & Celikyilmaz, 2022). For example, prefix tuning optimizes continuous vectors (numerical representations of data) in pre-trained language models for specific tasks, using 'virtual tokens' instead of distinct ones (Liu *et al.*, 2021). Virtual tokens are continuous, numerical representations of textual elements that can be manipulated and optimized within the model's vector space, offering greater flexibility compared to discrete tokens. On the other hand, prompt tuning applies backpropagation (an algorithm for training neural networks by minimizing the error between the network's predictions and the actual output, allowing the network to learn and improve its performance on various tasks) to train a frozen language model to produce input prompts for particular tasks (Lester, Al-Rfou, & Constant, 2021). In contrast to these approaches, prompt engineering concentrates on manually creating and revising prompts, aligning it more with human-centred fields such as human-computer interaction, and conversational AI, rather than the general field of machine learning (Oppenlaender, Linder, & Silvennoinen, 2023).

This article aims to explore AI prompt engineering as a digital competence using a narrative and critical literature review. We aimed to develop a comprehensive understanding of the intricacies involved in AI prompt engineering and assess its role as a digital competence by examining various dimensions, techniques, challenges, and applications across multiple domains. We asked the following research questions:

1. What are the key dimensions and aspects of AI prompt engineering as a digital competence?
2. What are the technological challenges faced in AI prompt engineering?
3. How is AI prompt engineering applied across various domains such as entrepreneurship, art, and science, and what is its impact in these areas?
4. What are the prominent techniques and strategies used in AI prompt engineering, and how do they contribute to its effectiveness as a digital competence?

The article initiates by outlining the methodological principles tied to the literature review. It then progresses to the crux of the piece, which applies a narrative and critical examination of the literature. Several key topics are delved into, such as digital competencies, the progression of prompt engineering techniques, technological obstacles within prompt engineering, and the utilization of AI prompt engineering across various fields. Subsequently, the article elucidates on AI prompt engineering strategies, founded on the analysis of diverse prompts including text-to-image and text-to-text prompting. It culminates with the final remarks, providing significant implications for educators and organizations.

RESEARCH METHODOLOGY

In this study, we employed a narrative and critical literature review, following the approach outlined by Ratten (2023), to delve into the various aspects of AI prompt engineering as a digital competence. By building upon existing research and prior literature, we sought to develop a comprehensive understanding of the intricacies involved in AI prompt engineering and its role as a digital competence.

The article systematically explores various dimensions of AI prompt engineering. By analyzing the academic and practitioner literature and conducting desk research, we created a list of potential themes related to AI prompt engineering, including the development of prompt engineering techniques, technological challenges faced in prompt engineering, and the application of AI prompt engineering across various domains like entrepreneurship, art, and science.

Moreover, we developed a conceptual framework that encompasses different strategies for AI prompt engineering. This framework highlights the significance of certain prompt techniques and provides specific examples from business settings.

LITERATURE REVIEW AND THEORY DEVELOPMENT

Digital Competences

The majority of studies on digital competences are related to the education industry, focusing on students' and teachers' abilities to use technology effectively in learning and teaching (Fernández-Batanero, Montenegro-Rueda, Fernández-Cerero, & García-Martínez, 2022; Pozo-Sánchez, López-Belmonte, Rodríguez-García, & López-Núñez, 2020) highlighting the need for continued improvement in this area (Falloon, 2020). These studies indicate the need for digital competences as a core, fundamental literacy addressing both technology mastery and a digital citizenship mindset, especially in higher education (Martzoukou, Fulton, Kostagiolas, & Lavranos, 2020).

Digital competences consist of a blend of knowledge, skills, and attitudes encompassing concepts, facts, skill descriptions (for example, the capability to execute processes), and attitudes (such as a mindset or inclination to take action) (VUORIKARI Rina, Kluzer, & Punie, 2022). Scholars indicate that digital competences transcend mere technical abilities and represent a complex concept that integrates a wide range of skills, including cognitive, emotional, and sociological knowledge, which are crucial for effectively navigating digital environments (Røkenes & Krumsvik, 2016; Wang, Zhang, Wang, & Li, 2021). Moreover, scholars emphasize the importance of critically and reflectively employing technology to generate new insights and knowledge (DeWitt & Alias, 2023; Głodowska, Maciejewski, & Wach, 2023). Over the years, a wide variety of frameworks and models have been developed and utilized to explore and understand digital competence from different perspectives (Blundell, Mukherjee, & Nykvist, 2022; Guitert, Romeu, & Baztán, 2021; Kelentrić, Helland, & Arstorp, 2017).

One of the most comprehensive developments in this area is the DigComp framework which offers a more in-depth and structured approach to understanding digital competence (Reisoğlu & Çebi, 2020). Created with the purpose of informing and guiding policies to enhance digital competencies for citizens of all age groups, the framework acknowledges the critical role digital skills play in the constantly changing digital landscape of today (Štaka, Vuković, & Vujović, 2022). The DigComp framework is structured around five core competence areas. Since 2016, these areas include information and data literacy, communication and collaboration, digital content creation, safety, and problem-solving

(VUORIKARI Rina *et al.*, 2022). This framework will be applied to conceptualize AI prompt engineering. We used the DigComp framework to analyze AI prompt engineering as a competence (Table 1).

Table 1. AI prompt engineering's overlap with other digital competences

Area		Competence	AI prompt engineering
1.	Information and data literacy	1.1. Browsing, searching, and filtering data, information, and digital content	✔
		1.2. Evaluating data, information, and digital content	✔
		1.3. Managing data, information, and digital content	✔
2.	Communication and collaboration	2.1. Interacting through digital technologies	✔
		2.2. Sharing through digital technologies	✔
		2.3. Engaging in citizenship through digital technologies	
		2.4. Collaborating through digital technologies	✔
		2.5. Netiquette	
		2.6. Managing digital identity	
3.	Digital content creation	3.1. Developing digital content	✔
		3.2. Integrating and re-elaborating digital content	✔
		3.3. Copyright and licenses	
		3.4. Programming	✔
4.	Safety	4.1. Protecting devices	
		4.2. Protecting personal data and privacy	
		4.3. Protecting health and well-being	
		4.4. Protecting the environment	
5.	Problem solving	5.1. Solving technical problems	✔
		5.2. Identifying needs and technological responses	✔
		5.3. Creatively using digital technologies	✔
		5.4. Identifying digital competence gaps	✔
		5.5. Learning in digital environments	✔

Source: own elaboration based on Vuorikari Rina *et al*., 2022.

AI Prompt Engineering

In recent years, AI prompt engineering has emerged as a critical aspect of interacting with large language models (LLMs) such as ChatGPT. By examining the literature, we can identify several themes that help us better understand the applications and implications of AI prompt engineering across various domains. Some of these themes include the development of prompt engineering techniques, the challenges faced by non-experts in prompt engineering, and the application of AI prompt engineering in different domains such as entrepreneurship, art, and science.

Development of Prompt Engineering Techniques

A notable theme in the literature is the ongoing effort to develop and improve prompt engineering techniques. White *et al.* (2023) presented a catalogue of prompt engineering patterns that can be applied to solve common problems in LLM conversations. Reynolds and McDonell (2021) introduced the concept of a 'metaprompt,' which is a higher-order prompt designed to seed the language model to generate its own natural language prompts for a range of tasks. The metaprompt approach aims to leverage the language model's inherent capabilities and understanding of natural language to create more effective and nuanced prompts. Instead of directly prompting the model with a specific task, the metaprompt encourages the model to generate appropriate prompts that could be used for the desired task. This approach can potentially lead to more accurate and creative results, as the language model leverages its vast knowledge to generate suitable prompts. Ekin (2023) provides a comprehensive guide on prompt engineering techniques, tips, and best practices for ChatGPT, a powerful tool in natural language processing (NLP) with applications across various industries. This guide covers the fundamentals of prompt engineering, effective prompt crafting techniques, best practices, advanced

strategies, and real-world case studies that demonstrate the practical applications of prompt engineering in customer support, content generation, domain-specific knowledge retrieval, and interactive storytelling. Ling *et al.* (2023) explored the use of reasoning chains as a prompting technique, which leverages structured sequences of related knowledge statements from external knowledge bases to improve the model's performance in open-domain commonsense reasoning tasks.

Moreover, researchers examined zero-shot and few-shot prompting techniques used in natural language processing to enable LLMs to adapt and generalize to new tasks with limited or no supervised training. Zero-shot prompting enables a model to make predictions about previously unseen data without the need for any additional training. This is achieved by framing NLP tasks as natural language prompts and generating responses that indicate the predicted output. However, performance in zero-shot settings often lags behind supervised counterparts, leaving room for potential improvement (Zhou, He, Ma, Berg-Kirkpatrick, & Neubig, 2022). Meanwhile, few-shot prompting is a technique, in which the model receives a small number of examples, typically between two and five, to quickly adapt to new tasks. This approach allows for the creation of more versatile and adaptive text generation models, often with less data required (Meyerson *et al.*, 2023).

Technological Challenges in Prompt Engineering

Another recurring theme is related to technological challenges in designing effective prompts. Bang *et al.* (2023) found that similarly to other LLMs, ChatGPT suffers from hallucination problems that refer to the phenomenon of LLMs generating plausible-sounding but incorrect or unsupported information in their responses. This issue can be particularly problematic, because it can lead to the dissemination of false or misleading information. However, the interactive feature of ChatGPT enables human collaboration with the underlying LLM to improve its performance through a multi-turn 'prompt engineering' fashion, *i.e.* an interactive approach in which users iteratively engage with a large language model (LLM) like ChatGPT in a conversational manner. In this approach, users provide input prompts and refine them over multiple turns or iterations based on the responses generated by the model. Li (2023) highlighted the legal and ethical risks associated with LLMs, including stochastic parrots. Stochastic parrot is a term used to describe LLMs' propensity to mimic and reproduce existing text from their training data without a deep understanding of the content. This behaviour can sometimes lead to biased, inappropriate, or irrelevant outputs. Zamfirescu-Pereira, Wong, Hartmann, and Yang (2023) found that non-AI-experts struggled to engage in end-user prompt engineering effectively, often lacking systematic approaches and overgeneralizing their experiences. This difficulty highlights the importance of addressing the challenges related to prompt engineering and the technological limitations of generative AI models, ensuring the safe and responsible use of LLMs across various applications.

Application of AI Prompt Engineering in Different Domains

Entrepreneurship: Short and Short (2023) demonstrated how LLMs can be effectively used to produce entrepreneurial rhetoric by mimicking celebrity CEO archetypes. This study underscores the potential for AI prompt engineering to revolutionize content creation and communication strategies in the world of entrepreneurship.

Art: Oppenlaender, Visuri, Paananen, Linder, and Silvennoinen (2023) investigated prompt engineering as a creative skill for generating AI art, emphasizing that expertise and practice are required to master this skill. This theme showcases the artistic potential of prompt engineering, opening up new avenues for creative expression and collaboration between humans and AI.

Science – data extraction: Polak and Morgan (2023) proposed the ChatExtract method using engineered prompts applied to a conversational LLM for accurate data extraction from research articles. This study highlights the potential for AI prompt engineering to streamline data extraction processes and improve the efficiency of research across scientific disciplines.

Healthcare: Wang *et al*. (2023) provided a comprehensive review of prompt engineering methodologies and applications in the healthcare domain. They highlight the significant contributions of prompt engineering to healthcare NLP applications such as question-answering systems, text summarization, and machine translation.

AI Prompt Engineering Strategies

Text to Image Prompting

Recently, there has been a surge in the number of text-to-image generation models based on LLM (DALL·E2, Stable Diffusion, Midjourney). Noteworthy, the construction of appropriate prompts depends on the tool used at the moment, even though there are general best practices for visual models. Building prompts for text-to-image models is conceptually simpler than for text-to-text models, as the number of tasks is limited in their case.

As mentioned, working with vision models has certain basic principles that we should follow to achieve the desired result. 1) It is important to use a variety of adjectives to give the generated image a desired atmosphere and climate; 2) We should determine the desired image quality, *e.g.* low resolution, HD or 4K; 3) The style of the image should be specified, such as surrealism, realism, expressionism or photorealism; 4) We should provide a reference name of the artist or creator – such as the name and surname of a painter, graphic designer, or photographer) – to help place the model in the style of a particular work and creator; 5) We should not place more than 2-4 objects in the image. If the number is higher than the generators usually start to become less precise and create blurred content. 6) It is important to be specific as the more specific and detailed the prompt is, the greater the chance of getting the desired result (Oppenlaender, 2022). Table 2 presents the final form of an effective prompt.

Table 2. Prompts examples

What do you see?	What is happening?	How does it look?	Results
Businesswoman	Full of energy, Working at the desk	In the style of Van Gogh	This prompt offers a precise description leading to more predictable and concrete imagery.
Fulfillment	While working in an NGO sector	4K	This prompt is more abstract, potentially yielding surprising and inspirational results for further exploration.

Source: own elaboration.

Another effective prompting strategy involves learning from existing examples. Resources such as Lexica, a database of images, and the prompts utilized for their generation via the Stable Diffusion tool, can be instrumental. Such databases can be navigated to identify desired outcomes or to find inspiration. In the context of brand artwork development or campaign creation, incorporating a consistent descriptive element as a reference point can be highly beneficial. For instance, when crafting artwork for a corporate website, a constant descriptor like 'Bauhaus geometric illustration from 1963' could be applied to each generated image. This approach would yield graphics that adhere to a uniform style, thereby establishing a cohesive visual identity for the website (Parsons, 2023).

Text-to-text Prompting

For models returning text, the creation of prompts usually relies on the desire to solve a specific language task, therefore, the prompt architecture differs from task to task. Table 3 summarizes AI PROMPT engineering recommendations.

Ultimately, an effective prompt may include the following elements: 1) Context – can include information about the role the model should play for the task or any necessary information about the situation that may ground it ('You are a salesperson in a technology company'); 2) Instruction – the task to be performed ('Write an email to a customer thanking for high attendance during the last workshop on MLOps'); 3) Input Data – data for few-shot learning or information the model should use to perform the task ('Customer name: XYZ, keywords to include = [future, innovation, parthership]'); 4) Expected output format – information about the format and type of output in which the answer is to be provided ('Provide just the email message content').

Table 3. Recommendations for the text-to-text AI prompts

Acronym	Recommendation	Description
A	Articulate the instruction	Clearly state the task to be performed, such as 'write,' 'classify,' 'summarize,' or 'translate,' and specify how the output should look (table, list, Python code).
I	Indicate the prompt elements	Show the model where the instructions and input data are and what the expected output format should be.
P	Provide ending cues and context	Offer the model clear ending cues, such as three dots for continuation or a colon, dot, or placeholder like 'answer:' for indicating a response is needed. Furthermore, ground the model by providing a context for the task (*e.g.* 'You are a manager of a tech team').
R	Refine instructions to avoid ambiguity	Give the model-specific instructions and a detailed description of the task to avoid any confusion or imprecision.
O	Offer feedback and examples	For conversational models, such as ChatGPT, feedback on the model's responses can help it better understand the desired output. Moreover, providing the model with a few examples of expected responses (few-shot learning) can help it adapt its style and way of responding.
M	Manage interaction	Treat the model as your sparring partner, asking it to provide counterarguments or point out flaws in your ideas.
T	Track token length and task complexity	Break complex tasks into smaller steps for better performance. Remember to control the token length, keeping the prompt and response under the token limits of the model (usually 4096 tokens for commercially available LLMs). The token length of a text can be checked here: https://platform.openai.com/tokenizer.

Source: own elaboration of AI prompts in ChatGPT and Bard.

Example 1: 'Tell me what prompt engineering is. Write briefly and without unnecessary details.' This example does not provide a clear structure for the response, nor does it indicate the intended audience. 'Briefly and without unnecessary details' is not a clear instruction. Example 2: 'Write a 3-5 sentence explanation of what prompt engineering is. Write the response as if it were directed to a high school student.*' This example provides a clear response structure and specifies the intended audience and thus signals the required tone and vocabulary to use in the response.

Table 4 presents best practices for prompts for frequent tasks that we undertake with the help of LLM. Remember to treat these examples as a good starting point for tests, as each task is individual and needs a specific matching prompt.

In many tasks, we need to combine the following building blocks to receive the expected result. For example, we can use transcripts from the call centre to extract important information and then generate an email based on this information which we will direct to the customer.

The implementation of efficient prompting strategies is essential for improving the performance of LLMs in all possible applications. By following the methods, guidelines, and best practices discussed in this article, users can acquire more accurate, relevant, and fitting responses from both text-to-image and text-to-text generative models.

Resources for AI Prompt Engineering

For the purpose of this article, we analyzed several resources that facilitate the process of prompt engineering in AI systems, such as ChatGPT and DALL-E. These resources range from platforms and databases, like PromptBase and Promptvine, which provide ready-to-use prompts or allow users to exchange their prompts with others. Open-source frameworks, such as OpenPrompt, offer another dimension to these resources. They provide a conducive environment for users to learn, experiment, and even design their own prompts, fostering the development of skills in prompt engineering. Communities also play a pivotal role in the AI and prompt engineering landscape. Platforms like Learn Prompting bring together enthusiasts from various backgrounds to share knowledge, experiences, and best practices. Such communities provide a thriving environment that fosters learning and growth in the AI field. Moreover, there are numerous tutorials and guides, like the Prompting Guide and OpenAI

Best Practices, that offer guidance on prompt engineering and general AI practices. These resources serve as invaluable tools, especially for beginners seeking to establish a solid foundation and understanding of AI techniques. Table 5 illustrates resources for AI prompt engineering.

Table 4. Examples of AI prompts for specific tasks and implementations

Task	Instructions	Example	Implementation
Question answering	Format the prompt so that it specifies where is the instruction, question, and placeholder for the expected answer. Explicitly state not to answer when unsure of the answer.	Context: the stock market in 2019. Question: What were the gains of the Nasdaq Composite in 2019? Answer:	Microsoft Customer Story-Strabag SE builds a risk management solution to improve efficiency using Microsoft Intelligent Data Platform (Microsoft, 2023b)
Text classification	Specify the classes that the model can choose to classify content. You can provide an example of a text and how it was classified in the given context to hint at what to pay attention to (few-shot learning).	Text: I recently purchased a new laptop... Classify if this text is: [complaint, review] Answer:	Microsoft Customer Story-KPMG augments current capabilities and improves the service delivery model with Azure OpenAI Service (Microsoft, 2023a)
Summary/ knowledge mining	Determine how long your summary should be or what specific information (types of information) you want to extract from the text. Determine the output format in which you want to receive the information (table, list of points).	Text: [transcript of a conversation from call centre Extract from the text: 1. Customer's name... 4. Write a summary of the conversation in 3-5 sentences. Return the result in bullet points.	–
Content generation	Provide grounding for the model. Specify the style of speech. Determine the expected length and format of the statement. Give an example of your style.	You are a copywriter for the XYZ company... Attributes: [blouse, yellow, lace, for summer]. The description must include information about the attributes and show the attractiveness of the product. The description must be 3-5 long sentences. Description:	Microsoft Customer Story-CarMax puts customers first with car research tools powered by Azure OpenAI Service (Microsoft, 2022)

Source: own elaboration based on Ekin, 2023.

Table 5. Resources for AI prompt engineering

Resource Name	Description	Link
Prompting Guide	Provides foundational knowledge on prompt crafting, methodologies, and models.	https://www.promptingguide.ai/
PromptBase	A large database of prompts compatible with ChatGPT, Midjourney, and DALL-E. It serves as a marketplace for buying and selling prompts.	https://promptbase.com/
OpenPrompt	An open-source framework that allows for the exploration of prompt learning. It facilitates experimentation with existing implementations and the creation of new exercises.	https://openprompt.ai/
ShareGPT	Offers a platform with over 31 000 posts and comments around ChatGPT and its commands. It serves as a plugin for learning and sharing new prompts.	https://sharegpt.com/
OpenAI Best Practices	Provides insights and best practices directly from OpenAI, aiding users especially at the onset of their AI journey.	https://help.openai.com/en/articles/6654000-best-practices-for-prompt-engineering-with-openai-api

Resource Name	Description	Link
Promptvine	A categorized database of prompts, along with plugins and tools dedicated to ChatGPT.	https://promptvine.com/
Prompt Engineering Guide	A GitHub repository with learning guides, tools, and additional information on prompt engineering.	https://github.com/dair-ai/Prompt-Engineering-Guide
Learn Prompting	An active Discord community with over 1000 members. It offers a wealth of documents and tutorials on prompt engineering.	https://learnprompting.org/
Awesome ChatGPT Prompts	A categorized collection of several hundred ChatGPT prompts, available free of charge.	https://www.awesomegptprompts.com/
Prompts AI	A platform that analyses text, checks user-selected settings, and provides suggestions on prompt improvement.	https://prompts.ai/
Openart	A database of 10 million prompts dedicated to graphic AI, including Stable Diffusion and DALL-E.	https://openart.ai/promptbook
Fusion AI	A free prompt engineering tool designed to assist with command improvement. It also features connections to other tools.	http://www.fusionai.world/

Source: own elaboration of online resources.

CONCLUSIONS

Artificial intelligence prompt engineering has been playing an increasingly crucial role in various fields, including entrepreneurship, art, science, and healthcare, thanks to its ability to generate targeted and meaningful interactions with LLMs. The DigComp framework, which outlines five core competence areas, *i.e.* information and data literacy, communication and collaboration, digital content creation, safety, and problem-solving provides a valuable lens to understand and improve AI prompt engineering competencies. The literature reveals a strong focus on the development of prompt engineering techniques, such as the use of metaprompts and reasoning chains, as well as zero-shot and few-shot prompting techniques. These methods are being refined continually to help LLMs adapt to new tasks with limited or no supervised training. However, there are still challenges to be addressed, including hallucination problems and the tendency for LLMs to mimic and reproduce the existing text without a deep understanding of the content. These issues can lead to the generation of false, misleading, biased, or inappropriate information. Furthermore, non-AI experts often struggle with prompt engineering, indicating a need for more accessible and systematic approaches.

Despite these challenges, prompt engineering has shown promising results in a variety of domains. In entrepreneurship, it can mimic celebrity CEO archetypes revolutionizing content creation and communication strategies. In art, it allows for new forms of creative expression. In science, it can streamline data extraction processes from research articles. Finally, in healthcare, it contributes significantly to applications like question-answering systems, text summarization, and machine translation.

In this study, we explored the significant implications of prompt engineering for AI practitioners, researchers, educators, and organizations. We demonstrated how effectively crafted prompts can enhance the outcomes generated by both text-to-image and text-to-text models. Such a skill can lead to the generation of more accurate and contextually relevant results, which in turn improves the overall performance and efficiency of the AI models.

For educators, our findings may serve as a valuable reference for teaching AI students about the role of prompt engineering in optimizing the performance of language models. The strategies and examples we presented could be integrated into curricula to further enrich the learning experience.

In the field of AI research, the strategies and best practices we shared can stimulate the development of more advanced prompt engineering techniques. Our study could also form the foundation for future research examining the impact of prompt engineering on language model performance.

For organizations incorporating AI into their operations, our study underlines the importance of investing time and resources into prompt engineering. By carefully formulating prompts, these entities

can derive increased value from their AI systems, as the models will then deliver more precise and helpful outputs.

Last but not least, our exploration yielded a valuable contribution to the field, *i.e.* the AI PROMPT framework. It provides clear, actionable recommendations for text-to-text prompt engineering, thus helping practitioners refine their prompts to elicit better responses from language models. The AI PROMPT framework emphasizes the importance of articulating instructions, indicating prompt elements, providing ending cues and context, refining instructions to avoid ambiguity, offering feedback and examples, managing interaction, and tracking token length and task complexity.

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Conflict of Interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Increasing customer equity through social media content and engagement

Angga Febrian

A B S T R A C T

Objective: The objective of the article is to investigate the impact of social media content on engagement and customer equity. The moderating role of the customer relationship is also analyzed. The purpose of this research was to find out the types of content that can increase engagement and customer equity and what is the role of customer relationships in strengthening the influence of that content.

Research Design & Methods: The online survey responses were collected from 250 respondents in Indonesia who have shopping experiences due to exposure to social media. I used structural equation modelling (SEM AMOS) to examine the relationship between variables.

Findings: Social media content can affect increased customer engagement and equity on social media. Good content must also contain several elements of entertainment that make customers want to linger on social media. Customer relationships can also strengthen the influence of content on social media engagement.

Implications & Recommendations: Marketers can strengthen content on social media with good customer relationships, such as being fast and responsive in their feedback.

Contribution & Value Added: This study provides new insights into creating a social media content marketing model that can strengthen customer relationships.

Article type:	research article
Keywords:	content digital; relationship customer; engagement; equity; social media
JEL codes:	M3, M31, M37

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INTRODUCTION

At the end of 2022, there will be 5.07 billion world internet users and 4.74 billion active on social media (We Are Social, 2022). These social media include Facebook, Instagram, Twitter, and Tiktok. Companies use many social media channels to reach a broader market. The use of information in the form of content can increase the involvement of fellow users on social media (Dolega, Rowe, & Branagan, 2021; Rajković, Đurić, Zarić, & Glauben, 2021). Creating and distributing content is essential for companies to fill space on social media (Shahbaznezhad, Dolan, & Rashidirad, 2021a). Marketers must understand what content is most appropriate to increase customer engagement which is the primary goal of content marketing on social media (Ho, Pang, & Choy, 2020; Lee, Hosanagar, & Nair, 2018). There are differences of opinion regarding what content is appropriate on social media and the difference lies in the research object (Ashley & Tuten, 2015; Bu, Parkinson, & Thaichon, 2021; Shahbaznezhad *et al.*, 2021a; Syrdal & Briggs, 2018). However, there are common features to social media content, namely, it must always contain information and be entertaining to increase customer engagement.

Previous research confirms that content marketing on social media can increase consumer engagement (Cao, Meadows, Wong, & Xia, 2021a; de Oliveira Santini *et al.*, 2020; van Doorn *et al.*, 2010). However, the previous literature is limited to the consequences of this content and regards no other

factors strengthening content marketing strategies on social media. Furthermore, the results cannot be applied to product sales on social media. Thus, it is necessary to reinforce several other factors that can increase consumer involvement on social media from the content submitted so that it can facilitate interaction among users. Previous researchers may have forgotten the concept of customer relationships in measuring its importance in maintaining relationships among users on social media. For example, if there is customer feedback in the form of questions or requests, marketers must respond immediately. This confirms that the role of customer relationships can improve business performance through social media (Charoensukmongkol & Sasatanun, 2017). This study aims to determine what type of content is most appropriate and explain why customer relations are required for effective content marketing that can increase customer engagement.

It is essential to understand that social media is not a selling media but a media for sharing content, collaboration, and interaction (Kim & Ko, 2012). If a company wants to market its products on social media, it must generate a desire to buy by providing exemplary service and solutions to problems faced by consumers (Kaplan & Haenlein, 2010). The close relationship between marketers and consumers must be maintained, because the features used on social media may not be as complete as e-commerce platforms, which are a place to sell. Selling on social media must also prioritize other factors that can strengthen the content delivered, such as customer relationships. Marketers focus on disseminating information and listening to their customers to get feedback that can be used to seek new ideas or improve existing ones (Wan, Paris, & Georgakopoulos, 2015).

Social media content and engagement are also related to generating customer equity in social media (Hapsari, Hussein, & Handrito, 2020; Ho et al., 2020; Ho & Chung, 2020; Yuan, Kim, & Kim, 2016). Customer equity is the key to long-term success in marketing, because it can create a competitive advantage (Rust, Lemon, & Zeithaml, 2004). Then the marketer's task is to increase customer equity and determine what factors are essential to pay attention to so they can be managed properly (Ou, Verhoef, & Wiesel, 2017; Razzaq, Yousaf, & Hong, 2017). Customer equity is the cornerstone of the success of the marketing model, which I have designed to be an exceptional social media content model.

To investigate the importance of customer equity for marketing success on social media, I built a research model aimed to examine the effect of social media content on social media engagement and increased customer equity. Customer relations are also used as a moderator to show whether they strengthen the relationship between these variables. My study contributes to the field in several ways and provides new insights regarding social media content marketing. Firstly, I added customer relationship variables to moderate the impact of social media content that had not been studied before. This conceptualization significantly expands and refines the content marketing model on social media. Secondly, I explored the factors that can shape customer equity based on content shared on social media. Thirdly, my study provides input for practitioners to improve the delivered content so that it has customer value that benefits the company.

This research is organized into several parts. The next section will discuss the literature review as a basis for conceptualizing research and empirical testing through the hypotheses developed. The third section will define the methodology used to analyze the research data. Section four will describe the research results by linking the empirical findings to theory. The last section will summarize the research results theoretically and practically and highlight the research limitations, which will become suggestions for future research.

LITERATURE REVIEW AND HYPOTHESES DEVELOPMENT

Social media has become popular in recent years. Many marketers use it for sales, which has proven effective (Czarnecka, Kinelski, Stefańska, Grzesiak, & Budka, 2022; Herzallah, Muñoz-Leiva, & Liébana-Cabanillas, 2022). Marketers adopt the uses and gratifications theory (UGT) (Katz & Foulkes, 1962), which is applied in social media (Plume & Slade, 2018). Social media content can satisfy active participants' needs, including information seeking, relationship building, self-presentation, and enjoyment (Buzeta, De Pelsmacker, & Dens, 2020; Jacobson, Gruzd, & Hernández-

García, 2020). When marketers improve the aspect of information sharing, social media will connect people more (Aslam, Muqadas, Imran, & Rahman, 2018).

The phenomenon of high narcissistic behaviour impacts followers' behaviour on social media conducing them to make self-presentations that show personal activities (Grieve, March, & Watkinson, 2020). Self-presentation is a person's attitude to presenting oneself to others to get attention (Baumeister & Hutton, 1987). A frequent example may be posting opinions and promoting other people's content that one is interested in. The desire to get feedback, such as comments and likes, is one of the goals of the presentation (Skogen, Hjetland, Bøe, Hella, & Knudsen, 2021). Furthermore, providing exciting videos and photos makes users enjoy social media (Kim, Shoenberger, & Sun, 2021). An example may be Instagram, which changed the type of content and started focusing on visual content and not words (Liao, Widowati, & Cheng, 2022). Ultimately, when marketers can deliver appropriate and valuable content, it results in engagement, interaction, and collaboration between marketers and customers, resulting in long-term business relationships (Cartwright, Liu, & Raddats, 2021). However, previous studies found that the delivered content could not make consumers like it (Kim, Spiller, & Hettche, 2015; Shahbaznezhad *et al.*, 2021a). This type of content is emotional, comes in the form of photos, and focuses on the number of written characters in the content created (Shahbaznezhad *et al.*, 2021a) (Li & Xie, 2020; Shahbaznezhad *et al.*, 2021a). This is why I did not use this type of content in this study to find out which types of content facilitate better increasing customer engagement on social media.

Rust *et al*. (2004) and Wang, Liu, Kim, and Kim, (2019) suggest using customer equity in identifying, predicting, and testing consumer behaviour in the long term. Customer equity is value creation resulting from customer relationships (Wang, Kim, Ko, & Liu, 2016). These results are obtained from maintaining long-term consumer relationships using marketing technology (Blattberg, Malthouse, & Neslin, 2009). Customer equity can be formed through value, brand, and relationship equity *(Wang et al*., 2020; Yuan *et al*., 2016). Value equity includes objectively assessing convenience, quality, and price recognition (Kim, Kim, & Hwang, 2020). Brand equity is defined as the liability of the brand and a set of assets related to the brand, such as its name and symbol (Aaker, 1992). Relationship equity evaluates consumer value perceptions of the company's product provision in achieving a learning relationship with customers (Ho & Chung, 2020; Rust *et al*., 2004). Previous research discussed the impact of marketing activities on social media that can affect customer equity (Kim & Ko, 2012). One of the activities is content production, which can drive brand experiences on social media (Yu & Yuan, 2019). This proves that content can create engagement and beneficial customer equity for the company. Thus, I hypothesise:

H1:   Social media content has a positive and significant effect on social media engagement.

H2:   Social media content has a positive and significant effect on customer equity.

Previous research discussed chiefly customer engagement strategies on social media that can provide benefits (Majeed, Asare, Fatawu, & Abubakari, 2022; Shang *et al*., 2022). Customer engagement behaviour is a concept that reflects consumer motivation towards social media content (Muntinga, Moorman, & Smit, 2011). I limited the conceptualization of consumer involvement to liking, commenting, and reposting other people's social media posts widely used in product marketing research on social media (Cao *et al*., 2021a; De Oliveira Santini *et al*., 2020). I followed the three dimensions of social media engagement: consumption, contribution, and creation (Cao *et al*., 2021a; Chahal & Rani, 2017). Together, these three dimensions constitute an indicator reflecting social media involvement. The most basic attitude is consumption which is defined as an activity carried out by users only to see and read information submitted by other users (Majeed *et al*., 2022; Schivinski, 2019). The next level is contribution. Users comment and share information with friends with similar thoughts and interests (Piehler, Schade, Kleine-Kalmer, & Burmann, 2019). The highest level of social media engagement is creation, which is posting photos or videos about other brands on social media (Cheung, Pires, Rosenberger, & De Oliveira, 2021).

In online business, customer engagement is closely related to customer equity (Ho & Chung, 2020). Customer equity refers to strategic methods that companies use to interact with their customers, which impact customer attitudes and behaviour (Cambra-Fierro, Xuehui Gao, Melero-Polo, & Javier Sese, 2019). Pleasure behaviour factor drives company's strategic design in pursuit of increasing com-

pany value (Kim, Ko, Kim, & Jiang, 2021; Pansari & Kumar, 2017). When customer equity can be achieved, it will indicate success in retaining customers and profitable customer satisfaction for the company (Kim et al., 2020; Ou et al., 2017). Thus, I hypothesise:

H3: Social media engagement has a positive and significant effect on customer equity.

Moreover, I predicted that there was a mediating role for social media engagement in the relationship between social media content and customer equity. Customer involvement is essential for achieving good performance in connecting customers and companies (Kim et al., 2021). Previous research showed that the mediating role of engagement can increase consumer attitudes in a direction that benefits the company (Alalwan et al., 2020; de Oliveira Santini et al., 2020; Gómez, Lopez, & Molina, 2019). Marketers' interaction becomes the foundation for increasing customer value (Morgan & Hunt, 1994; Sheth, & Parvatiyar, 1995). This interaction occurs when marketers can provide entertainment when accessing social media, which has implications for increasing customer equity (Yuan et al., 2016). Thus, I hypothesise:

H4: Social media engagement mediates the influence of social media content on social media engagement.

If marketers want to increase the number of visitors on social media, they need to incorporate the concept of customer relationships into business processes (Guha, Harrigan, & Soutar, 2017). Listening, understanding, and appreciating customers are essential to building customer relationships in transactional marketing (Andzulis, Panagopoulos, & Rapp, 2012). Customer relationships can be created through customer intimacy, trust, and active empathetic listening (Gautam & Sharma, 2017; Park, Doreen Chung, Gunn, & Rutherford, 2015; Sulaiman, Baharum, & Ridzuan, 2014). Customer intimacy is the perception that marketers and customers have close relationships and interact with each other (Sulaiman et al., 2014). Furthermore, trust can also create customer relationships (Nguyen & Khoa, 2019). Trust is crucial in the relationship marketing theory (Morgan & Hunt, 1994). The final form of customer relationship is active empathetic listening, a willingness to hear and understand other people during social interactions (Bletscher & Lee, 2021). This good relationship can strengthen customer engagement, because the companies can thus get the information they need from customers (Cui & Wu, 2016; Wang, 2021). Like effective social media marketing on Facebook, the company must provide products or services that strengthen customer relationships with others and can adjust advertisements according to customer needs (Zhu & Chen, 2015). The overall research model is shown in Figure 1.

H5: Customer relationship moderates social media content on social media engagement.
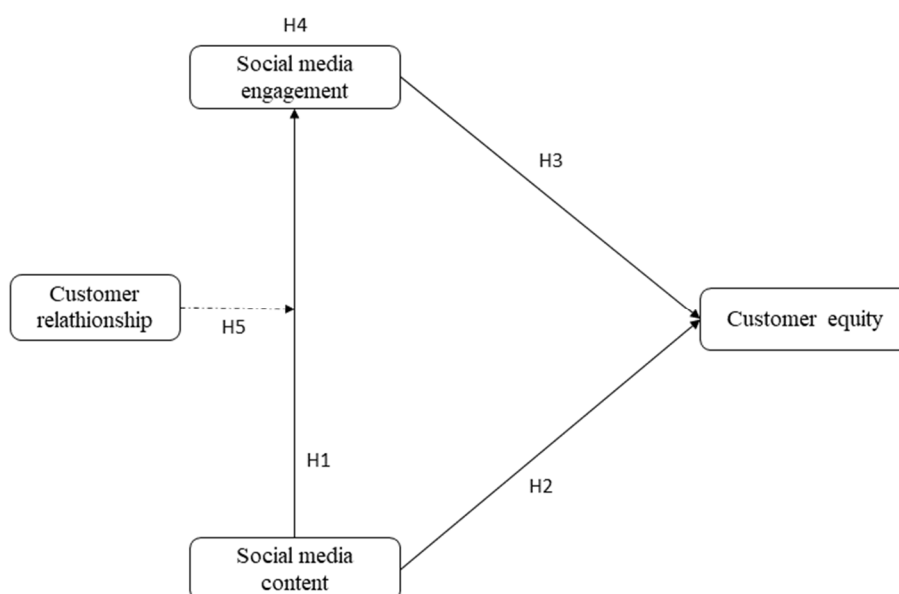
Figure 1. The theoretical model
Source: own elaboration.

RESEARCH METHODOLOGY

This study applied a quantitative method using a questionnaire survey distributed to respondents with online shopping experience due to exposure to social media in 2022 in Indonesia. To facilitate sampling, I used Google Forms and Whatsapp as the media for distributing the questionnaires. In total, 300 samples were collected but only 250 were used for data analysis because they avoided outliers and had a good level of reliability (Hair, Babin, & Krey, 2017a). To ensure that the respondents understand the questions, the researcher directly assisted the respondent in filling out all the answers. I analysed consumer behaviour from their online shopping habits through social media stimuli. It makes sense to measure the feelings and feedback of social media users through a questionnaire. Table 1 displays the demographics of respondents categorized by gender, age, education, access to social media, and the product they wanted to buy.

The questionnaire was distributed by explaining several questions to respondents who were adopted from previous research questions. Social media content is measured by four dimensions: information sharing, relationship building, self-presentation, and enjoyment (Jacobson *et al.*, 2020). Four dimensions measure social media engagement: consumption behaviour, contribution behaviour, and creation behaviour (Cao, Meadows, Wong, & Xia, 2021b; Chahal & Rani, 2017). Customer relationships are measured by three dimensions: customer intimacy, trust, and active empathetic listening (Gautam & Sharma, 2017). Customer equity is measured by 13 questions derived from value, brand, and relationship equity (Yuan *et al.*, 2016). The survey used a 5-point Likert scale '1 = strongly disagree' and '5 = strongly agree.'

The study used covariance-based structural equation modelling (SEM) with statistical testing using Amos 24. The SEM approach was appropriate for use in this study, because it can measure online behaviour with large data with complex models and the existence of latent phenomena (Hair *et al.*, 2017a). I took several steps to complete this study. Firstly, I analysed and performed statistical tests with confirmatory factor analysis (CFA) to ensure that the data was normally distributed, valid, and reliable for research measurement. After the data was considered good, I tested the hypothesis through direct testing between constructs and looking at mediation and moderation effects. The goodness of fit criteria was also considered in each model.

Table 1. Demographics of the research sample (*n* = 250

Characteristics	Category	Frequency (People)
Gender	Male	95
	Female	155
Age	< 21	105
	> 21	145
Education level	High School	144
	Bachelor	67
	Postgraduate	39
E-commerce brand	Instagram	123
	Facebook	73
	Tik Tok	46
	Twitter	5
	Whatsapp	3
Product	Fashion (shirts, pants, shoes)	181
	Electronic	51
	Food & Beverage	18

Source: own elaboration.

RESULTS AND DISCUSSION

Customer-based structural equation modelling was performed in two stages (Hair *et al.*, 2017a). Firstly, the confirmatory factor analysis (CFA) model was measured to see the construct model's

validity and reliability. Secondly, a structural model was used to test the hypothesis by looking at direct, mediation, and moderation effects.

Measurement Model

In multiple regression, data normality plays an essential role in data processing (Farooq, 2016). The value of 1.96 for Skewness-Kurtosis is an accepted condition ensuring that the data is normally distributed and there are no outliers (Byrne, 2013; Hair *et al.*, 2017a). The following criterion is checking validity divided into two types, namely convergent validity and discriminant validity (Awang, Wan Afthanorhan, & Asri, 2015). Convergent validity starts by looking at the loading factor ≥0.5 and summing it into the average variance extended (AVE) value which is used to show the average variance between variables with an acceptable cut-off ≥0.4 (Fornell & Larcker, 1981). All constructs range from 0.42 to 0.70 higher than the cut-off value. Discriminant validity is also tested to see how the measured construct differs from other constructs. Table 2 and Figure 2 explain the results of calculating the measurement model in structural equation modelling. All constructs had values that met the requirements. Consistency of results on all items was also carried out with the same test to get a good reliability value. The calculation of the reliability coefficient was seen from the composite reliability value, which is suggested to have a minimum value of 0.6 in all constructions ranging from 0.67 to 0.91, higher than the limit value (Bagozzi & Yi, 1988; Ferine, Aditia, Rahmadana, & Indri, 2021). The fit of the results of the conceptualization of the measurement model could be accepted in the fit index, GOF (0.930), RMSEA 0.065, TLI (0.961), and NFI (0.944) (Hair, Babin, & Krey, 2017b). The research instrument was valid and reliable to be used for hypothesis testing.

Absolute Fit Measure
Chi-Square = 0.12104
Probability =1.3569
CMIN DF = 0.2051
GOF = 0.93
RMSEA = 0.64

Incremental Fit Measure
TLI = 0.96
NFI = 0.94
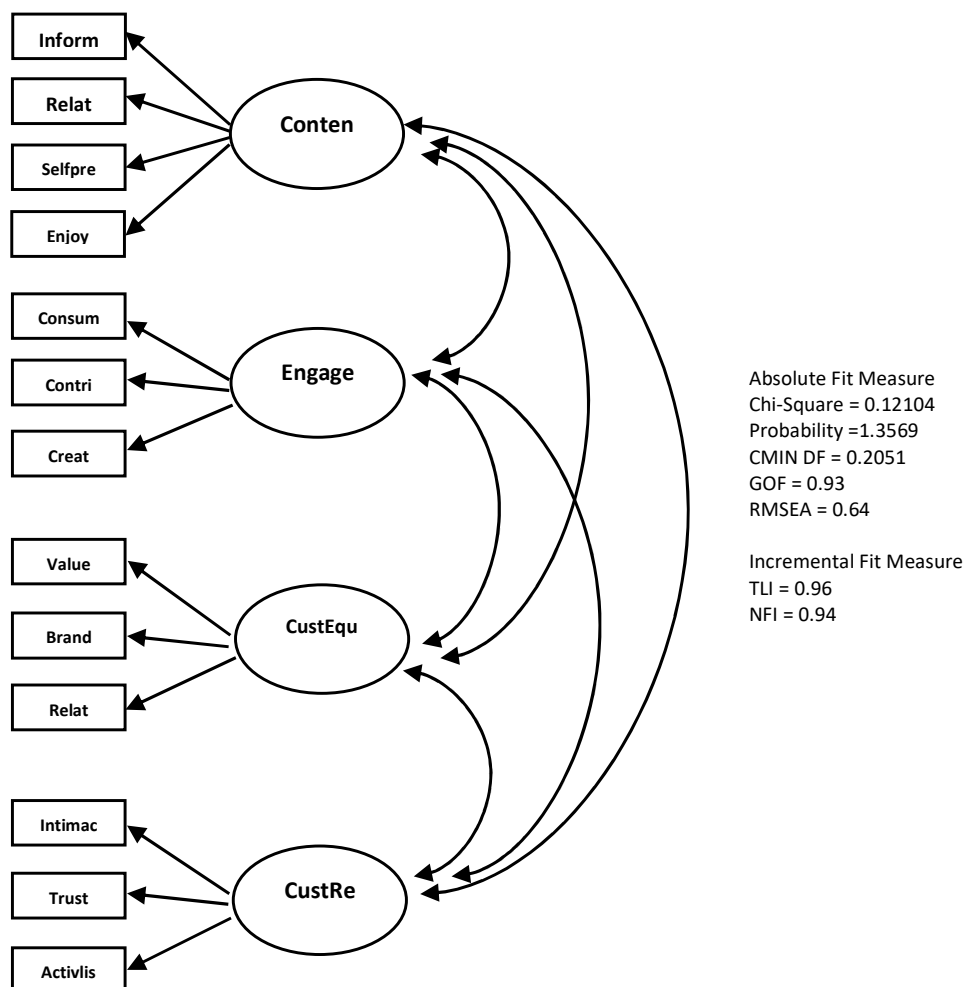
Figure 2. Standardized measurement model
Source: own elaboration.

Table 2. Summary of the measurement model

Construct	Coding	Loading	Average variance extracted	Discriminant validity	Composite reliability
Relationship building	RB3	0.7	0.50	0.70	0.75
	RB2	0.673			
	RB1	0.739			
Self-presenta-tion	SP3	0.762	0.58	0.76	067
	SP2	0.778			
	SP1	0.75			
Enjoyment	ENJ3	0.674	0.57	0.76	0.80
	ENJ2	0.879			
	ENJ1	0.702			
Information sharing	IS3	0.65	0.42	0.65	0.68
	IS2	0.656			
	IS1	0.633			
Consumption behaviour	Consu4	0.639	0.59	0.77	0.85
	Consu3	0.799			
	Consu2	0.832			
	Consu1	0.777			
Contribution behaviour	Contri4	0.697	0.55	0.74	0.83
	Contri3	0.725			
	Contri2	0.799			
	Contri1	0.745			
Creation behaviour	Creat4	0.754	0.72	0.85	0.91
	Creat3	0.928			
	Creat2	0.922			
	Creat1	0.78			
Customer intimacy	Intim3	0.824	0.66	0.81	0.85
	Intim2	0.783			
	Intim1	0.825			
Trust	Trust5	0.8	0.66	0.81	0.91
	Trust4	0.796			
	Trust3	0.868			
	Trust2	0.817			
	Trust1	0.775			
Active listening	Activ4	0.753	0.70	0.84	0.90
	Activ3	0.871			
	Activ2	0.868			
	Activ1	0.859			
Value equity	Val4	0.774	0.53	0.73	0.82
	Val3	0.636			
	Val2	0.769			
	Val1	0.734			
Brand equity	Brand4	0.719	0.61	0.78	0.86
	Brand3	0.825			
	Brand2	0.776			
	Brand1	0.794			
Relationship equity	Relat5	0.837	0.64	0.80	0.90
	Relat4	0.836			
	Relat3	0.739			
	Relat2	0.773			
	Relat1	0.812			

Source: own elaboration.

Structural Models

The effect of independent variables on the dependent variable can be described by a structural model (path coefficient). Mediation and moderation tests are integrated complexly. The SEM method can do it well (Berraies, Ben Yahia, & Hannachi, 2017; Irfan, Qadeer, Abdullah, & Sarfraz, 2022). The initial results by testing the CFA met the validity and reliability. Next, the proposed model was tested with a structural equation model considering the maximum likelihood estimation. Table 3 shows the results of testing the hypothesis directly, starting from social media content having a positive and significant impact on social media engagement which supports the validation of hypothesis 1 (β 1.075, p <0.001). Testing the second hypothesis showed social media content's positive and significant effect on customer equity (β 0.447, p <0.001). Testing the third hypothesis showed that social media engagement positively and significantly impacted customer equity (β 0.325, p <0.001).

Table 3. The results of the hypothesis testing

Hypothesis	Estimate	Standardize estimate	Critical Ratio	P-Value	Result
H1: Cont → Engage	1.075	0.146	7.370	0.000	Supported
H2: Cont → CustEqu	0.447	0.135	3.303	0.000	Supported
H3: Engage → CustEqu	0.325	0.091	3.592	0.000	Supported

Source: own elaboration.

This study also examined social media engagement as a mediating effect between content and customer equity. The mediating effect can be seen from the sum of the direct and indirect effects through the variance accounted-for value (VAF). Hair Jr *et al.*, (2021) and Sarstedt, Ringle, Smith, Reams, and Hair (2014) determine three categorizations of VAF. Firstly, VAF > 80% results in full mediation. Secondly, 20% ≤VAF ≤80% results in partial mediation. Lastly, VAF <20% means no mediation. Table 4 shows the value of VAF, which is indicated to have a partial mediating effect (β = 0.473, VAF = 47%). Thus, I confirmed that social media engagement partially mediates the relationship between social media content and customer equity. Therefore, H4 was supported.

Table 4. Engagement mediation effects

Hypothesis	Path			Calculation result			Result	
	A	B	c'	Ab	ab+c	ab/ab+c		
H4:Content → Engage → CustEqui	1.015	0.368	0.415	0.3735	0.7885	0.4736	47%	Partial Mediation

Source: own elaboration.

We conducted an in-depth analysis to examine the moderating effect of customer relationships on the relationship between social media content and engagement shown in Figure 3. The sum of the interaction values generated from the three variables produced a significant value (β 0.005, sig < 0.01), shown in Table 5. I also display in Figure 4 the line with high customer relationship above the line showing low customer relationship. This indicates that when marketers strengthen and enhance the role of customer relationships, the content delivered can enhance social media engagement further. The higher the customer relationship the company develops with its consumers, the more they are willing to interact on social media.

Table 5. The moderating effect of customer relationship

Moderation structural relation	Estimate	Standardized estimate	Composite reliability	P-value
Engage ← Content	0.511	0.099	5.140	0.00
Engage ← CustRelat	0.273	0.069	3.951	0.00
Engage ← Interaction	0.005	0.001	5.716	0.00

Source: own elaboration.

Hi-Square : 0.777
Probabilitas : 0.2241
CMIN DF : 0.1992
GOF : 0.94
RMSEA : 0.63
CFI : 0.98
TLI : 0.97
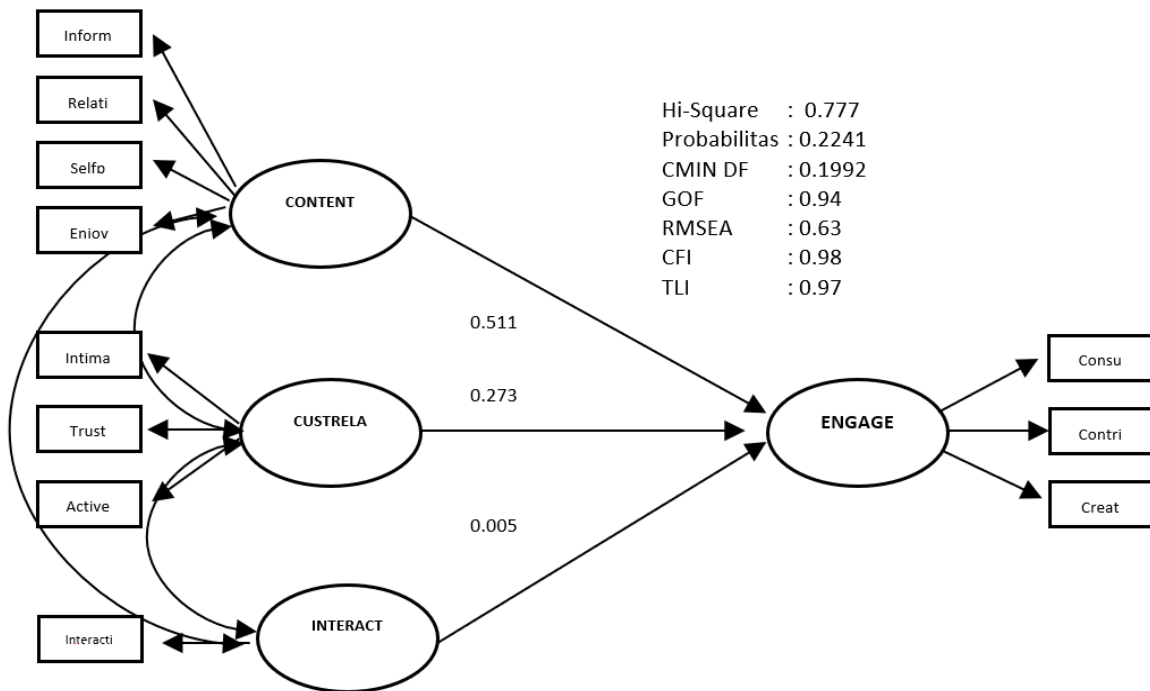
Figure 3. The interaction moderation model
Source: own elaboration.
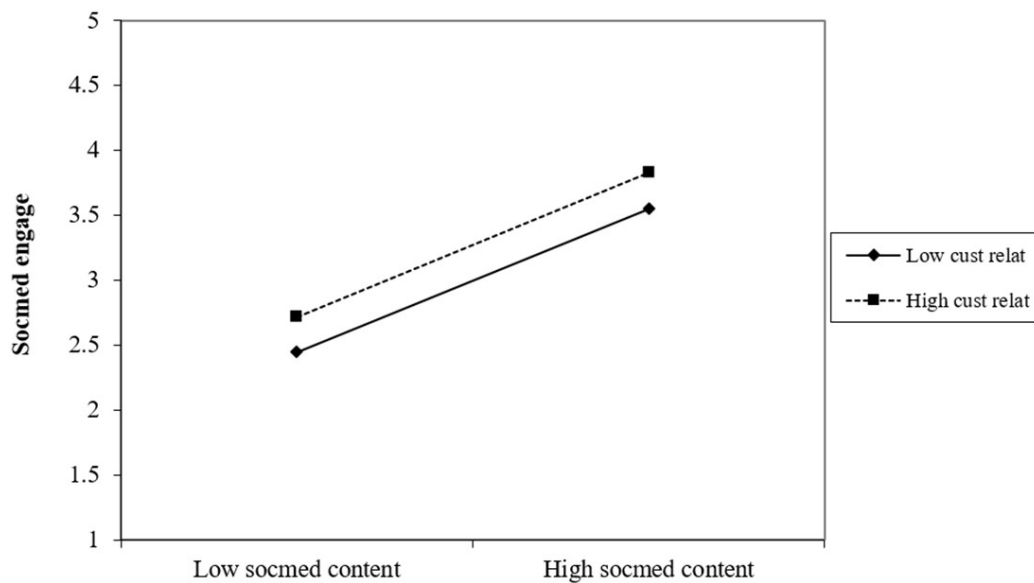
Figure 4. Moderating impact of customer relationships on social media content
Source: own elaboration.

Discussion

The main objective of this study was to investigate the influence of social media content on social media engagement and customer equity, the mediating role of social media engagement, and the moderating role of customer relationships in influencing these two variables. The study results showed that social media content has a positive and significant relationship with social media engagement (Hypothesis 1). This finding aligns with existing research (Bene *et al.*, 2022; Lappas, Triantafillidou, & Kani, 2021; Li & Xie, 2020; Majeed *et al.*, 2022; Pancer, Philp, & Noseworthy, 2022; Shahbaznezhad, Dolan, & Rashidirad, 2021b). Content shared on social media is proven to increase consumer engagement. I assessed that

content comes from consumer motivation to access social media. This motivation is divided into several reasons: wanting to share information with others, finding new friends, presenting oneself as the best, and finding entertainment through content transmitted by others. Bearing these reasons in mind, marketers can determine the right content according to consumer motivation to access social media. Creating and designing content must create value for consumers (Demmers, Weltevreden, & van Dolen, 2020). The content must have the same values that can generate engagement, because the impact of content produced on different social media may have different results (Voorveld, van Noort, Muntinga, & Bronner, 2018). This can be seen from the respondents accessing various social media such as Facebook, Instagram, Tiktok, Youtube, and Twitter to see the products' marketers. When involved in social media, users want to get something they expect. Examples include appreciation and response attention from marketers (Majeed, Owusu-Ansah, & Ashmond, 2021). Engagement manifests in the form of liking, commenting, and sharing content if the users are happy with the content received.

According to my findings, social media content has a positive and significant effect on customer equity, hence marketers should create content that drives and generates customer equity (Hypothesis 2). Previous research (Sharma, Singh, Kujur, & Das, 2021; Ibrahim, 2021) also emphasizes that entertainment content is a factor forming content that can increase customer equity. Entertainment includes funny content and exciting information in the form of photos and videos that are often shared on Facebook and Instagram. However, entertainment content is currently shared on e-commerce platforms, which do not use social media as their foundation (Zhang, 2020). This indicates that all platforms now use the concept of enjoyment to attract users' interest in accessing social media, which has implications for increasing customer equity. Exciting content is essential to increase equity, because it can improve company performance.

Moreover, the study found that social media engagement positively and significantly affects customer equity (hypothesis 3). This finding aligns with previous studies (Kim & Ko, 2012; Kim *et al.*, 2021). The higher the engagement shown, the higher the creation of customer equity that benefits marketers. The findings show that the highest engagement level, namely creation, is a factor that influences the formation of customer equity. These results explain that the marketers' activities aimed to create engagement must lead to the formation of creation, such as voluntarily reposting content received and recommending it to other followers. It is not enough to create engagement only in the form of likes and comments.

We tested the mediating role of social media engagement, which obtained partial mediation results (Hypothesis 4). Social media engagement was also used as mediation in previous research (Kim *et al.*, 2021), which focused on the relationship between digital services and customer equity. These results explain the importance of mediation in connecting the stimulus carried out in digital marketing on social media with the resulting consequences, namely customer equity. However, what needs to be considered is that the platform used must adapt to the company's goals, namely increasing customer equity, for example through Instagram for entertainment or via Twitter for conveying information (Pelletier, Krallman, Adams, & Hancock, 2020). Equity is formed not only from brands but also from the relationships and values formed. Even though it is proven that content can directly influence increasing customer equity, the findings explain that it can also be through engagement. This means that marketers must also pay attention to the role of engagement in shaping customer equity.

Lastly, I looked at the customer relationship moderation relationship. The moderating role of customer relationships refers to the level of its use, which influences the relationship between social media content and engagement variables (Hypothesis 5). The first step to creating customer engagement on social media is interacting directly with customers (Lacoste, 2016). Interactions at high and low levels were found to have a significant effect. The influence of the customer relationship can strengthen the relationship between the two variables. It can be interpreted that the content delivered to consumers will be better if a good customer relationship accompanies it, which involves, *e.g.*, responding quickly when there is feedback from consumers, keeping promises, and listening to input or complaints from consumers willing to be actively involved in social media. However, currently, marketers focus on the content of posts to increase engagement but forget the critical role of having a customer relationship. Marketers must master this skill to sell products on social media (Qalati, Yuan, Khan, & Anwar, 2021; Sedalo, Boateng, & Kosiba, 2022).

CONCLUSIONS

This study examined social media content's influence on engagement and customer equity. Through the perceptions of consumers accessing social media, we can learn their motivations for accessing social media. This knowledge can then be taken into consideration by marketers to determine the right strategy for marketing on social media. I also investigated the mediating variable, namely social media engagement, and the moderating variable, customer relationship. The results revealed that social media content (information sharing, relationship building, self-presentation, and enjoyment) significantly influences engagement and customer equity. Social media engagement was also found to have the ability to influence increased customer equity directly or indirectly. Marketers' ability in customer relationships was found to moderate the relationship between social media content and engagement. When marketers can demonstrate strong customer relationships, those relationships will get stronger. Therefore, marketers can use customer relationships to strengthen the influence of the delivered content in forming engagement.

Implications Theory

This study contributes to the literature regarding the effects of social media content marketing. Firstly, this study adds to the literature on the impact of social media content on increasing engagement and customer equity. This study also examined the direct effect between variables and the mediating effect of social media engagement and customer relationship moderation. The proposed research model adds to and strengthens the basic concepts of the digital content marketing model (Katz, Blumler, & Gurevitch, 1973; Rowley, 2008) adopted on social media. The previously unresearched novelty of this research lies in creating a digital content marketing model on social media by incorporating the moderating role of customer relationships as a relationship booster. Thus, relationship marketing theory (Sheth, 2002) has value in digital marketing in the current era.

Practice Implication

Social media is very effective in marketing products (Al Halbusi, Alhaidan, Abdelfattah, Ramayah, & Cheah, 2022; Ali Abbasi, Abdul Rahim, Wu, Iranmanesh, & Keong, 2022; Fraccastoro, Gabrielsson, & Pullins, 2021; Obermayer, Kővári, Leinonen, Bak, & Valeri, 2022). One of the effective ways that I offer is a content marketing model that can help marketers create content to increase customer equity. Customer equity is a valuation metric for predicting business continuity performance (Wang *et al*., 2020). Some of the findings can be used as input for policymakers or marketers. Firstly, this study found that the content desired by customers on social media refers to entertaining, self-presenting, relationship-building, and informative content. For example, entertaining content shows photos and videos that make others laugh. Informative content can be in the form of information related to or outside the product. Therefore, companies selling products on social media need not limit themselves to offering products but can provide other details associated with product characteristics. For example, by selling fashion products, they can create content about what colour of clothes suits a night party.

Secondly, this study found that the influence exerted by customer relationships strengthened the content delivered to increase customer engagement. Engagement plays an essential role in sales success on social media. Marketers expect consumer feedback through viewing and re-sharing posts from marketers. This two-way communication shows that there is a need for a relationship strategy to strengthen the created content strategy, which might have been ignored in previous studies. When consumers provide involvement in the form of the content created, marketers must immediately be able to offer a fast and reliable response. Marketers can give special internal assignments to provide exceptional services that handle every consumer question and provide relevant information from the content created. However, it is not limited to just creating content. It must be ready to offer services to build consumer relationships through real-time direct communication and the person must have good product knowledge.

Research Limitations

This study has several limitations that can provide insight for further research. Firstly, it did not focus on specific social media or provide in-depth findings on the assessment of each social media. Future research can focus on one social media to determine the right type of content. Each social media will have a different assessment in attracting and satisfying consumer needs (Foss, Klein, & Bjørnskov, 2019). The characteristics of each social media are different. Secondly, this study limited its investigation to social media used as a support medium for online sales, which may limit the generalizability of the findings. Therefore, future research can investigate the same model with its e-commerce application, thereby increasing the external validity of the research model findings. Thirdly, most of my survey respondents were young people who are highly interested in and skilled at using social media. However, they do not fully have high purchasing power compared to the older age groups. Therefore, for further research, it is possible to reach the younger generation and the older generation, or even different country cultures, so that the approach becomes a role model for research in general.

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Conflict of Interest

The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Women and female entrepreneurship: Past, present, and future trends in developing countries

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A B S T R A C T
Objective: This article provides an understanding of the knowledge structure based on the publications on women's entrepreneurship in developing and emerging countries based on bibliometric analysis. Women entrepreneurs play a pivotal role in economic and social development.
Research Design & Methods: By analysing citations, co-citations, and co-words, this study unveiled the most significant publications in the study context, link their knowledge structure, and map future research direction based on the two analyses, respectively. From the Web of Science (WoS), 208 journal publications were obtained.
Findings: Four themes were discovered in the co-citation analysis: 1) differences between men and women entrepreneurs, 2) the development of women's entrepreneurship, 3) challenges among women entrepreneurs in developing countries, and 4) progress in women's entrepreneurship studies. Subsequently, four themes were discovered in the co-word analysis: 1) innovation in women's entrepreneurship, 2) women's entrepreneurship performance, 3) empowerment of women entrepreneurs, and 4) self-employment and assistance to women entrepreneurs.
Implications & Recommendations: Theoretical and practical implications are presented by enhancing and developing women's entrepreneurship participation in developing countries.
Contribution & Value Added: This review provides a comprehensive knowledge structure based on the past, present, and future trends in women's entrepreneurship in developing countries.

Article type:	research article
Keywords:	women's entrepreneurship; developing countries; emerging countries; bibliometric analysis; gender equality
JEL codes:	L26, O57

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INTRODUCTION

Women represent nearly half of the working population, but their participation in specific areas of the workforce, such as entrepreneurship, is underrepresented (Strawser *et al*., 2021). Women's role in economic development and nation-building is no longer an issue of human rights or social justice, but rather an integral component in the ecosystem aiming to attain sustainable development (Shah & Saurabh, 2015; Foss *et al*., 2019). Women's presence in the labour force has been more than significant. It is crucial for job creation and economic growth, particularly in developing countries (Welsh *et al*., 2018). Women's participation is deemed more relevant than ever in these countries (De Vita *et al*., 2014; Correa *et al*., 2022).

Despite their contribution to economic growth, there has been disparity and significant differences in the way they are treated, such as receiving lower wages compared to men (Jha *et al*., 2018). Especially in the context of developing and emerging countries, women are still primarily associated with domestic responsibilities and family obligations (*e.g*., children's upbringing, caring for the elderly and

the sick, and attending to house chores) (Yousafzai *et al.*, 2015). As the world progresses, women's socio-economic status has improved, but some issues persist in social equity and equality, discrimination, atrocities, and violence committed against them.

There is a significant knowledge gap in studies reviewing women's entrepreneurship involvement. There have been several studies that revied women's entrepreneurship in the developing countries context (De Vita *et al.*, 2014; Panda, 2018; Rashid & Ratten, 2020; Correa *et al.*, 2022) and reviews on women entrepreneurs in general (Cabrera & Mauricio, 2017; Bastian *et al.*, 2018; Chreim *et al.*, 2018; Foss *et al.*, 2019). Regardless of the reviews available in the study context, no review provided a comprehensive knowledge structure on the subject from the bibliometric approach, except for Moreira *et al.* (2019). Despite adopting such a method, Moreira's study did not provide a detailed analysis of co-citation and co-word analysis that would capture researchers' understanding of women's entrepreneurship based on the knowledge structure of the network among key publications and plausible future trends.

This study was motivated by two premises. Firstly, it aimed to provide the perspective of equality and equity in entrepreneurship without bias or discrimination on gender. Regardless of the prevalent importance of women's entrepreneurship in economic development and social growth through job creation, wealth capitalization, and innovations, many suggested that entrepreneurship lingered around gender differences (Neumeyer *et al.*, 2019; Nair, 2020). Some urged to remove the barriers to women's entrepreneurship to pave the way for equal investment opportunities (Carter *et al.*, 2015).

Secondly, since the full potential of women's entrepreneurship has not been reached, there is still much room for growth and development (Strawser *et al.*, 2021). For such growth to be realized, implicit knowledge structure in women's entrepreneurship must be understood and factors that hinder such progress must be addressed. Thirdly, there is a lack of theoretical understanding regarding women's entrepreneurship in the literature reviews, particularly in the context of developing countries. Several relevant studies have provided a significant overview of the phenomenon. For instance, Panda (2018) reviews women entrepreneurs' challenges and constraints in developing countries, suggesting that the top priority is to address the business, economic, and political environments. Bastian *et al.* (2018) present a narrative review of women's entrepreneurship in the Middle East and North Africa. The study found that there is a lack of theoretical foundations at the macro level comprising culture and religion and at the organizational level within the scope of ethnic groups by acknowledging the complex cultural, social, and religious diversity of the region.

Furthermore, in acquiring the knowledge structure, even limited studies performed science mapping through bibliometric analysis. Aggarwal and Johal (2021) present a bibliometric analysis of rural women's entrepreneurship by conducting a performance analysis on the top published authors, countries, institutions, and journals. Despite these relevant studies, according to the authors' knowledge, there has yet to be a study that reviewed women's entrepreneurship in developing countries through bibliometric analysis. There is a need to further explore this topic as there is a pertinent gap in understanding the fundamental research streams from the literature on the current context. As such, to explore the structure of this subject, this study uncovered such phenomena from bibliometric perspectives in addressing the following research objectives:

1. To investigate the knowledge structure of women's entrepreneurship through co-citation analysis.
2. To evaluate and predict the evolution of future trends in women's entrepreneurship through co-word analysis.

This article is structured as follows. We will first discuss the role of women's entrepreneurial contribution to economic development. Next, we will elaborate on the specific role of women entrepreneurs in developing countries. Then, we will explain the methodology applied using the bibliometric analysis. Subsequently, we will highlight the discussion points based on the study context and present the theoretical and practical implications. The article will close with a conclusion and suggestions for future work.

LITERATURE REVIEW

Women's entrepreneurship involvement has been recognized as a significant contributor to developing countries' economic growth (Isaga, 2019; Shastri *et al.*, 2019; Sahu *et al.*, 2021). Due to the lack of jobs in the mainstream workforce, entrepreneurship drives economic growth and helps generate employment opportunities, reducing poverty, and raising living standards (Zeb & Ihsan, 2020). According to Worlddata.info, in developing countries, the standard of living, income, economy, and development are well below average (World Data, 2022). Currently, there are 152 developing countries with a population estimated at 6.62 billion people, amounting to 85.22% of the world population. Countries categorized as developing countries include the whole of Africa, Central and South America, almost all Asian countries, and the majority of the island states (World Data, 2022).

In most developing countries, men have control over women within a patriarchal society (Xheneti *et al.*, 2019; Zeb & Ihsan, 2020). Women are restricted from venturing into business and entrepreneurship activities. They are expected to look after their families and stay at home to fulfil household chores, while men go to work. Thus, entering the job market or being an entrepreneur is a big challenge for women in today's modern society (Essers *et al.*, 2021; Nasir *et al.*, 2019). They face gender discrimination, a lack of resources and infrastructure, work-family conflict, capital difficulty, and an unstable economic and political environment (Panda, 2018; De Clercq & Brieger, 2021). A geographically concentrated study would provide a colossal understanding of the factors that constrain women entrepreneurs in developing nations (Panda, 2018).

Women are motivated to start businesses and become entrepreneurs based on pull-push factors. Pull factors are driven by independence, social status, autonomy, and personal control, while push factors are related to low salary and job satisfaction (Al Matroushi *et al.*, 2020). The challenges women entrepreneurs face in developed and developing countries come from external and internal factors (Isaga, 2019). Challenges include work-family conflict, financial constraints, unstable business, lack of training, infrastructure, and economic and political environment (Panda, 2018). Despite facing similar challenges, women in developing countries face more unpredictable constraints than women in developed countries. Women in developed countries face less gender discrimination and are treated equally to men in society, thus leading to greater opportunities to venture into entrepreneurship. They are more likely to secure suitable jobs as society is more open to women becoming entrepreneurs (Cardella *et al.*, 2020).

In contempt of the importance of women's entrepreneurship, emerging and developing countries are facing low entrepreneurial education among their people due to institutional voids (Yadav & Unni, 2016). Women struggle in entrepreneurship as they face financial problems, socio-cultural bias, and lack of motivation, leading to low self-esteem. There are many opportunities and constraints in increasing women's participation in entrepreneurship (Moreira *et al.*, 2019). There is an urgent need for policy reform to change the social structure affecting women's involvement in the workplace especially in developing countries (Cho *et al.*, 2020; Asravor & Acheampong, 2021). Understanding women's entrepreneurship through this particular lens would enhance the current understanding of entrepreneurship from a macro perspective, particularly by drawing urgent attention to the cultural and institutional levels and how gender equality impacts women in developing regions. In essence, this review will provide an overview of the structures and dimensions of women's entrepreneurship which requires further studies and the development of gender equality.

RESEARCH METHODOLOGY

Bibliometric Analysis

In recent years, scholars have adapted the bibliometric approach in reviewing the knowledge structure in supplement to meta-analysis and qualitative systematic literature review. Applying a bibliometric analysis enables researchers to map the knowledge structure and link the relationship between different disciplines, publications, scholars, countries, and institutions (Zupic & Carter, 2015). VOSviewer software

version 1.6.17.0 was utilized as the tool in this bibliometric analysis. The software is useful for two main reasons. It 1) creates knowledge maps and 2) visualizes and explores maps based on bibliographic databases (van Eck & Waltan, 2014). To meet the objective of this review, two analyses were proposed:

− Co-citation analysis: The analysis explores the intellectual linkages within a discipline (Hota *et al.*, 2020; Farrukh *et al.*, 2022). Co-citation analysis assesses the similarity between documents, authors, or journals (McCain, 1990). The main function of the analysis is to show that when two items are cited together, the higher their content is (Zupic & Carter, 2015). To investigate the knowledge structure of the current topic, this study utilized document co-citation analysis as a means to evaluate the structural linkages between these publications.
− Co-word analysis: Co-word analysis is a form of content analysis method that applies the words in documents to link and build the structure of a discipline (Callon *et al.*, 1983). The analysis extracts the keywords from various parts of the publication, including the title, abstract, and keywords (van Eck & Waltman, 2014). The underlying idea is that when words appear frequently, the concept behind such words is related to each other (Zupic & Carter, 2015).

Search Strategy and Data Collection

A specific and detailed search string was applied through the WoS database consisting of two main domains of women's entrepreneurship and developing countries (Table 1). The search strings covered all relevant articles related to women's entrepreneurship, developing countries and other related words and terminologies. The asterisk symbol '*' in wom*n and other words in the search string would capture all words, including 'women' and 'woman.' The search utilized the 'topic' field in the WoS database to extract publications based on the keywords in the title, abstract, and keywords. The WoS is the best database as it is the most reliable and robust database available (Mongeon & Paul-Hus, 2016). Furthermore, the WoS's Journal Citation Report is the best-known indicator for evaluating research activity for top peer-reviewed journals. Recent studies have also adopted the WoS as the database for their bibliometric analysis (Shonhe, 2020; Akintunde *et al.*, 2021; Küster-Boluda *et al.*, 2022).

The review only included journal publications, leaving out conference proceedings, book chapters, and books to ensure that only peer-reviewed publications were included in the analysis to ensure the quality inclusion of documents. Moreover, we have limited publications until 2021 to include the only full calendar year for a better understanding based on the publication structure on a full-year basis. The search and data retrieval were conducted on 4 February 2022.

Table 1. Search string adapted via WOS

String	Justification
'wom*n entrepreneur*' OR 'female entrepreneur*' OR 'gender entrepreneur*' OR 'wom*n business*' OR 'wom*n firm*'	To identify literature on women entrepreneurs
'developing countr*' OR 'developing econom' OR 'emerging countr*' OR 'emerging econom*'	To identify literature on developing countries

Source: own elaboration.

RESULTS AND DISCUSSION

Descriptive Analysis

The initial search resulted in 242 publications. After limiting to only journal publications until 2021, the final list amounted to 208 publications. There was no restriction on the timeframe, generated from as early as 1970 up to 2021. The number of citations was 2804 with 2497 without self-citations. The average citation per item was 13.48, with an h-index of 25. Figure 1 shows the number of publications and citations of the 208 publications on women's entrepreneurship in developing countries. The first known publication in this field was found in 1996, but the pace started in 2007. The topic is highly anticipated and expected to grow higher in the coming years as developing countries are highly populated, leading to pertinent issues like unemployment and job security.
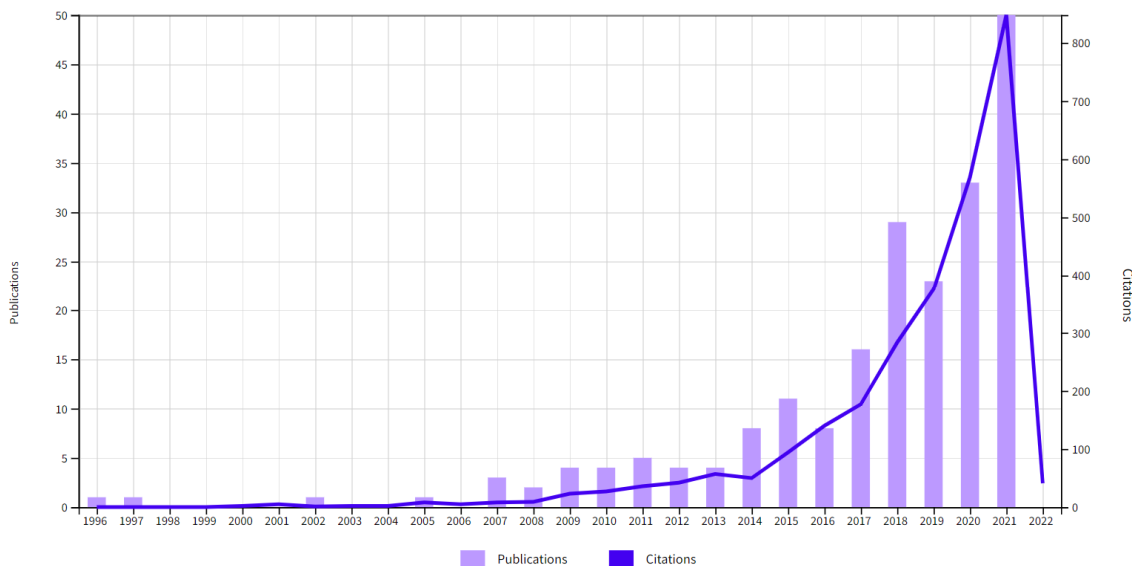
Figure 1. Number of publications and citations
Source: Web of Science.

Co-citation Analysis

From 11.629 cited references, 68 met the threshold of 10 cited references. The network analysis was built on women's entrepreneurship in developing countries based on these 68 cited references. The highest co-cited publications were Jamali (2009) (45 times), Ahl (2006) (40 times), and De Vita *et al*. (2014) (36 times). Table 2 lists the top 10 documents with the highest co-citation with their total link strength. Subsequently, Figure 2 illustrates the co-citation network that provides knowledge of the node's strength and positioning related to citation.

Table 2. Top 10 documents in women's entrepreneurship with the highest co-citation and total link strength

Documents	Citation	Total link strength
Jamali D, 2009, Gend Manag, v24, p232	45	410
Ahl H, 2006, Entrep Theory Pract, v30, p595	40	337
De Vita I, 2014, Eur Manag J, v32, p451	36	340
Brush CG, 2009, Int J Gen Entrep, v1, p8	34	337
Baughn CC, 2006, Entrep Theory Pract, v30, p687	29	299
Roomi MA, 2008, J Entrep, v17, p59	27	198
Jennings JE, 2013, Acad Manag Ann, v7, p663	26	261
De Bruinn A, 2007, Entrep Theory Pract, v31, p323	25	232
Amine LS, 2009, Entrep Region Dev, v21, p277	24	221
Minniti M, 2010, Eur J Dev Res, v22, p277	22	165
Langowitz N, 2007, Entrep Theory Pract, v31, p341	20	162

Source: own elaboration using VOSviewer analysis.

Co-citation analysis produced four clusters, as shown in Figure 3. The following bullet points discuss each of the clusters by specifying labels based on the author's inductive interpretation:

− Cluster 1 (red) was labelled 'Differences between men and women entrepreneurs.' There is a significant difference between men and women entrepreneurs according to the literature. Morris *et al*. (2006) asserted that women make a deliberate choice to venture into entrepreneurship and become entrepreneurs. They have a clear sense of the cost and benefits of growth in entrepreneurship and understand their trade-off decisions. Klapper and Parker (2011) discovered that women venture into different entrepreneurial activities than men. Women excelled in labour-intensive sectors such as

trade and services compared to capital-intensive sectors such as machinery and manufacturing. Performance gaps between male and women entrepreneurs in three regions were analysed by Bardasi *et al*. (2011) (Latin America, Europe and Central Asia, and Sub-Saharan Africa). Findings revealed a significant difference in firm size but a smaller gap in firm efficiency and growth between male and female-owned firms. Female entrepreneurs were found to be less successful than male entrepreneurs due to low startup capital, less business human capital obtained from prior work experience, and a lack of work experience in family-owned businesses (Fairlie & Robb, 2009). The study also discovered that female entrepreneurs work fewer hours and have different business goals than men.
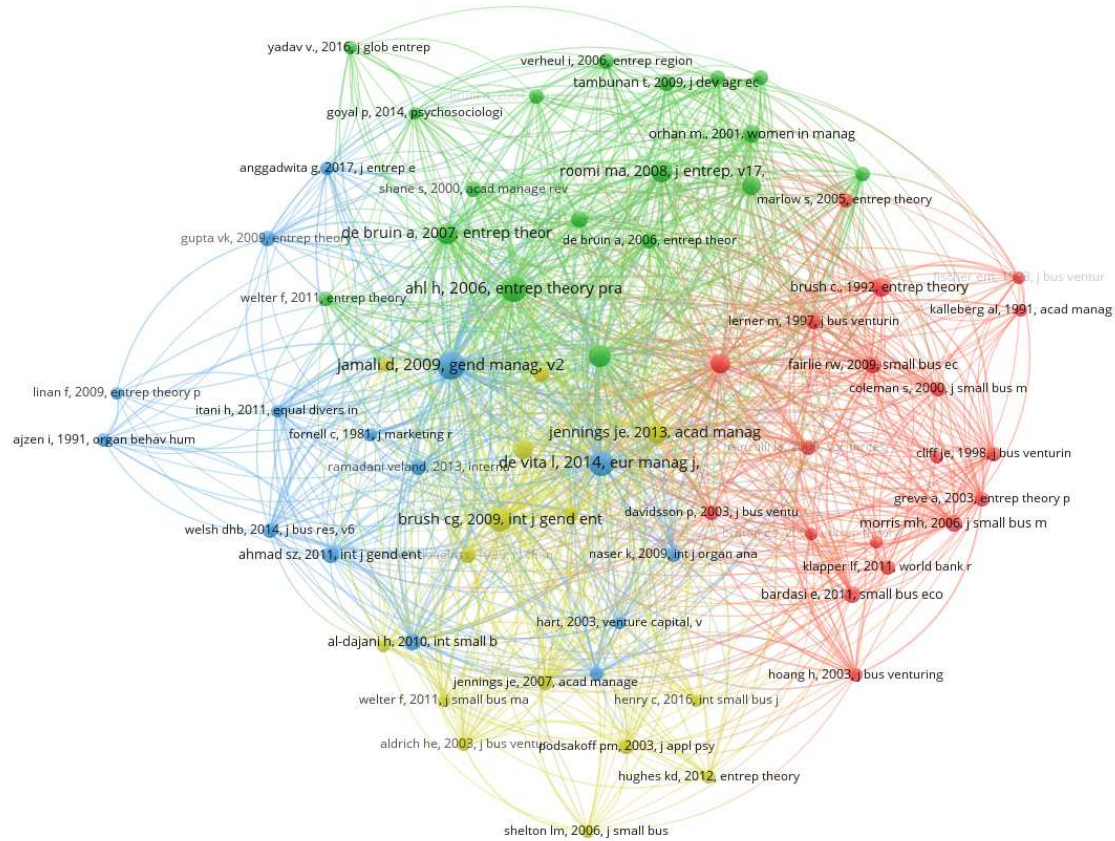
Figure 2. Network of co-citation analysis
Source: own elaboration using VOSviewer.

- Cluster 2 (green) was labelled 'Development of women's entrepreneurship.' This cluster posits the idea of the creation of women-led businesses. Brush and Cooper (2012) delineate the Diana Project International as a platform for women entrepreneurs and business-oriented growth. The platform develops, conducts, and shares through facilitation from international scholars. Ahl (2006) suggests that a new research direction is needed to reproduce women entrepreneurs by capturing the wealthier aspect of the business. It is further reiterated by De Bruin *et al*. (2007) that dramatic growth in women's entrepreneurial participation is needed to expand the body of knowledge in both generic and specific theoretical understanding. Findings suggest that multi-agency cooperation is needed to foster development in women's entrepreneurship. Government agencies, educational policymakers, and the media should cooperate in providing business development access for women through local, regional, and national networks (Roomi & Parrot, 2008).
- Cluster 3 (blue) was labelled 'Challenges among women entrepreneurs in developing countries.' Jamali (2009) captures insight into the challenges and barriers among Lebanese women and discovered the relevance of micro-, meso-, and macro-level factors on the complexity women entrepreneurs face. With the existing gap in theoretical and empirical findings, De Vita *et al*. (2014) present a systematic literature review on women entrepreneurs in developing countries. Barriers are differ-

ent based on geographical location, including social and cultural factors. Anggadwita *et al.* (2017) explored the role of the socio-cultural environment on women's entrepreneurial behaviour in Indonesia. The findings show that women entrepreneurs need to overcome socio-cultural environment issues, especially in a multi-diverse socio-cultural environment like Indonesia.

– Cluster 4 (yellow) was labelled 'scholarship of women's entrepreneurship studies.' Brush *et al.* (2009) opined that 'motherhood' is a metaphor that represents the female entrepreneurs within the household and family context, having a more significant impact on women than men. Minniti and Naude (2010) review the understanding of motivations, constraints, and issues in female entrepreneurs in developing countries. Jennings and Brush (2013) demonstrated that entrepreneurship is a gendered profession, in which women entrepreneurs had come a long way, surpassing man developmental milestones. It was also described that entrepreneurship is derived from family activities, results from necessity and opportunity, and that becoming an entrepreneur is not necessarily motivated by economic gain. Henry *et al.* (2016) explore the methodological innovation in women's entrepreneurship scholarship. Due to the lagging of women's entrepreneurship research, it was suggested that radical qualitative and innovative methodologies like in-depth interviews, case studies, life histories, ethnography, and discourse analysis be employed to further understand the subject (Henry *et al.*, 2016). This would offer the opportunity to delve deeper into women's entrepreneurship endeavour and thus better understand it rather than unduly criticise it.

Table 3. Co-citation clusters on women's entrepreneurship in developing countries

Cluster	Cluster label	Number of articles	Representative publications
1 (red)	Differences between men and women entrepreneurs	19	Klapper and Parker (2011), Bardasi *et al.* (2011), Morris *et al.* (2006), Fairlie and Robb (2009)
2 (green)	Development of women's entrepreneurship	18	Ahl (2006), De Bruin *et al.* (2007); Roomi and Parrot (2008), Brush and Cooper (2012)
3 (blue)	Challenges among women entrepreneurs in developing countries	15	Jamali 2009, De Vita *et al.* (2014); Anggadwita *et al.* (2017)
4 (yellow)	Progress in women's entrepreneurship studies	15	Brush *et al.* (2009), Jennings and Brush (2013), Minniti and Naude (2010), Henry *et al.* (2016)

Source: own elaboration.

Co-word Analysis

Using the same database, we analysed the co-word knowledge structure of women's entrepreneurship in developing countries. From 968 keywords, 55 met the occurrences eight times. The highest co-occurrence keywords were gender (99), women entrepreneurs (76), and entrepreneurship (46). The list of the highest 15 co-occurred keywords is presented in Table 4.

The network visualization of the co-word analysis of women's entrepreneurship is presented in Figure 3. From the network, it can be deduced that there are four distinct clusters on the topic. Each cluster provides the knowledge structure on the likely future trends in women's entrepreneurship. Each cluster was labelled based on the link of the keywords that appeared based on the author's qualitative assessment:

– Cluster 1 (red). Cluster 1 comprises 18 words and was labelled as 'Innovation in women's entrepreneurship.' Innovative ideas among entrepreneurs are considered essential in today's challenging environment. They are needed to identify startup opportunities, new employment, revive of social networks, and increase productivity (Jha *et al.*, 2018). They are more crucial in developing countries as these countries must develop a balanced approach between national and entrepreneurial framework that relies on national strategic development. Nair (2020) discovered that stakeholders' engagement and involvement could enhance women's entrepreneurship innovation. Innovation has greatly influenced women's entrepreneurial performance (Zeb & Ihsan, 2020). Women with technological innovation ideas would determine higher productivity and acquire better results. It is argued that women with innovativeness would be able to succeed not

only in entrepreneurship, but also in other aspects of life, such as contributing to countering climate change through the promotion of awareness (Lemaire *et al.*, 2021).

Table 4. Top 15 keywords in the co-occurrence of keywords analysis

| Ranking	Keyword	Occurrences	Total link strength
1.	Gender	99	480
2.	Women entrepreneurs	76	338
3.	Entrepreneurship	46	188
4.	Female entrepreneurship	40	201
5.	Performance	40	171
6.	Developing-countries	33	183
7.	Impact	30	154
8.	Women	29	99
9.	Business	27	158
10.	Developing countries	27	127
11.	Growth	21	116
12.	Emerging economies	21	105
13.	Women's entrepreneurship	21	80
14.	Female entrepreneurs	18	74
15.	Firm performance	17	91

Source: own elaboration.
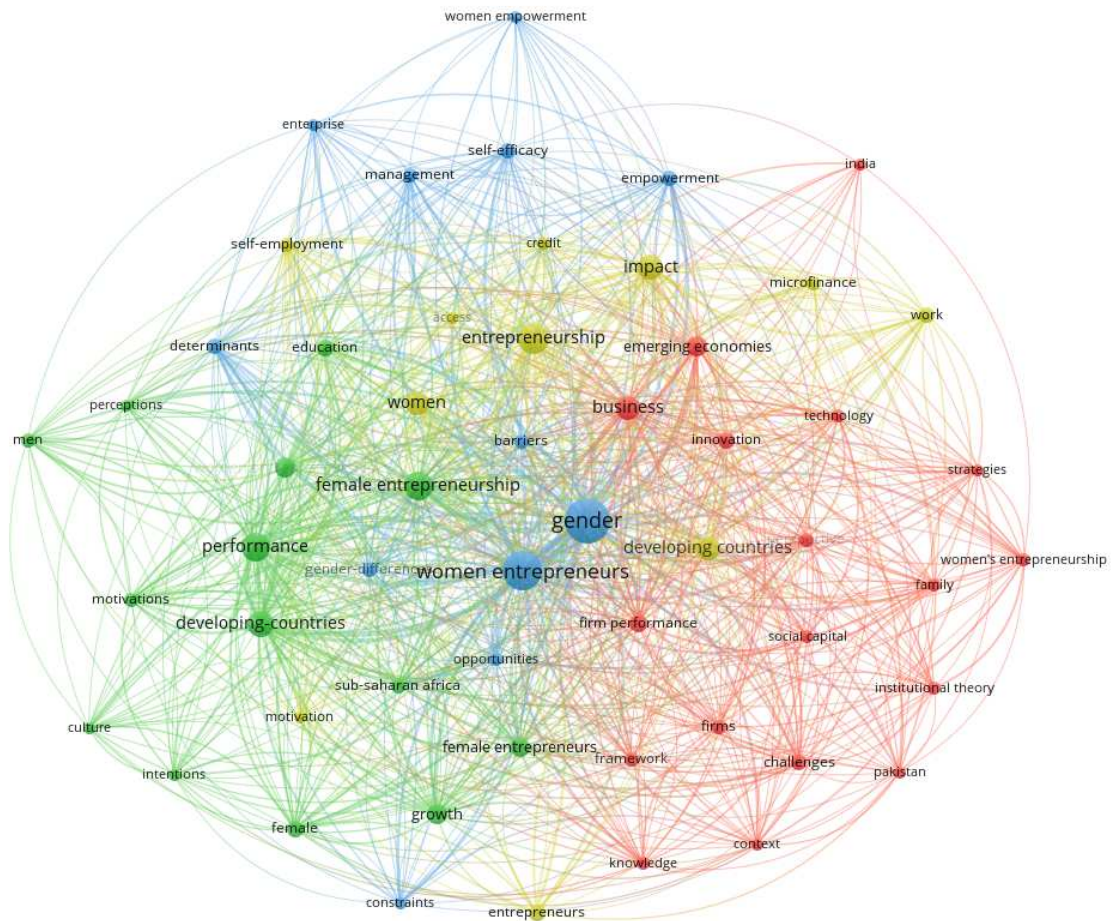
Figure 3. Network of co-citation analysis
Source: own elaboration using VOSviewer.

- Cluster 2 (green): With 14 words, this cluster was labelled 'self-efficacy and performance.' An essential part of empowering women is to enhance their self-efficacy. It is a crucial component of women's entrepreneurial activity (Kazumi & Kawai, 2017). Self-efficacy is the crucial aspect of psychological capital that positively impacts the self-regulation of individuals' complex decision-making capabilities. Self-efficacy influences one's perceived feasibility, desirability, and entrepreneurial potential, leading to entrepreneurial intention (Chhabra *et al*., 2020). Women are more influenced by self-efficacy compared to men (Cho *et al*., 2020), which ultimately impacts their performance, positively or negatively, in comparison to men. Empirical studies have shown that self-efficacy increases when women are exposed to role models, especially family members (*e.g.*, parents, siblings, or husbands) and are likely to become entrepreneurs (Austin & Nauta, 2015). The use of technology has increased women's self-efficacy to be involved in entrepreneurship (Ajjan *et al*., 2019). Through technology, women are able to transform their economic lives by reshaping and changing their day-to-day activities (Crittenden *et al*., 2019). Advancement in technology usage would bridge women in many socio-economic developments and thus increase their self-efficacy in entrepreneurship.
- Cluster 3 (blue): This cluster comprises 12 keywords and is labelled 'empowerment of women entrepreneurs.' Through entrepreneurship, women can be a source of empowerment that contributes to social change (Essers *et al*., 2021). A piece of growing empirical evidence shows that entrepreneurship has brought changes in economic benefits and social change through women empowerment in developing countries (Haugh & Talwar, 2016; Kabeer *et al*., 2017). Empowerment is defined as expanding people's ability to make strategic life choices in a context, in which this ability was previously denied to them (Kabeer, 1999). Women's empowerment is primarily influenced by culture (Lenka & Agarwal, 2017). In many developing countries, particularly in Asia, women faced inferior status due to traditional culture and religious beliefs (Cho *et al*., 2020). Furthermore, women's leadership has been a challenging issue with the notion of appointing women to high-ranking appointments remaining a taboo in many parts of the world.
- Cluster 4 (yellow): Consisting of 12 keywords, this cluster was conceptualized and labelled as 'self-employment and assistance to women entrepreneurs.' Based on Figure 3, it can be seen that cluster 4 is closely related to cluster 3, as some of the words are interchangeably linked within the two clusters. Empowerment is somewhat subjective, while assistance and aid are more objective in a way that tends to be more tangible. Women in developing countries are drawn to self-employment to earn more money and anticipate reducing the unemployment rate (Zhu *et al*., 2018). Self-employment provides more time flexibility, as women in developing countries are more likely to take care of the family and children than women in developed countries. They have more independence and the ability to control their work conditions. Despite the opportunity to become self-employed, women face different problems and challenges compared to men (Gupta & Mirchandani, 2018; Laudano *et al*., 2019). They face adversity in pursuing their entrepreneurship endeavour in accessing institutional finance, lengthy processes, collateral disputes, conservative attitudes, preconceptions, and suspiciousness leading to complicacy in the loan process (Ghosh *et al*., 2018).

Table 5 summarizes the co-word analysis on women's entrepreneurship in developing countries, comprising cluster number and colour, cluster label, number of keywords, and representative keywords.

RESULTS AND DISCUSSION

The main focus in women's entrepreneurship revolves around gender differences in social equality (Jha *et al*., 2018; Strawser *et al*., 2021). Social equality concerning many aspects of gender lies in cognitive bias, where society fails to recognize women's social progress in the twenty-first century (Georgeac & Rattan, 2022). Certain cultures and countries fail to note that the world has advanced and society has modernized. Most of the time, women excel in their ventures when provided the same opportunities and chances. Women should face only the same obstacles as men and be given full access to equal opportunities. The influence of social capital in women entrepreneurial venturing. The 'social' in social capital belongs to the individual but is found in the relationship network (Muniady *et al*., 2015). Social capital in women's entrepreneurship can be described as the potential or actual resource for women to

venture into entrepreneurship that embeds social ties (Nahapiet & Ghoshal, 1998). It is found to significantly influence enterprise outcomes (Stam *et al.*, 2014). Social capital is crucial in building a theoretical foundation in the entrepreneurial ecosystem underlying social stratification (Neumeyer *et al.*, 2019). Such a foundation is evident in the high-growth venture context, in which women face eminent barriers to advisors and mentors as network resources (Carter *et al.*, 2015). Evidence demonstrates that women acquire selective resources from family members while being restricted from accessing social capital outside their families (Lindvert *et al.*, 2017). Among the three social capital domains (cognitive, structural, and relational), structural is deemed the most critical in developing women entrepreneurs' values and norms (Muniady *et al.*, 2015). It can be enhanced and developed by creating a better communication system that can provide better access to resources and knowledge. Other forms of social capital in the form of marital status and wasta were found to be significant predictors of Muslim women entrepreneurs in the Middle East and North Africa (Baranik *et al*., 2018).

Table 5. Co-word analysis of women's entrepreneurship in developing countries

Cluster number and colour	Cluster label	Number of keywords	Representative keywords
1 (red)	Innovation in women's entrepreneurship	18	Business, emerging economies, innovation, technology
2 (green)	Self-efficacy and performance	14	Performance, female entrepreneurship, growth, motivations
3 (blue)	Empowerment of women entrepreneurs	12	Gender, women entrepreneurs, women empowerment, empowerment
4 (yellow)	Self-employment and assistance to women entrepreneurs	11	Entrepreneurship, impact, credit. Microfinance, self-employment

Source: own elaboration.

Many scholars have conceptualized the 'masculinization' of entrepreneurship based on the self-image of entrepreneurs (Kuschel *et al*., 2020). Such discriminatory terminology is against the well-rounded promotion of merit, based on one ability and success, instead of bias mindset. To combat such stereotypes and achieve social equality, the broader entrepreneurship background needs to adopt social feminism to elevate the stature of women in entrepreneurship (Asravor & Acheampong, 2021). Through such a notion, women's role would be expanded beyond home-based chores and more towards radically changing society. Women's entrepreneurship in developing countries is well-rounded from the institutional-theory perspective, providing a profound view of the constraints of women's entrepreneurship in developing countries. The theory suggests that women lie in a conservative and patriarchal society, viewing women as conventional mothers and wives (Panda, 2018). The institutional theory suggests that the society's institutional framework comprises a holistic involvement of politics, social and legal grounds to establish the production and support of women entrepreneurs (Orobia *et al*., 2020). The theory describes that institutions in such a way could help or diminish women venturing into entrepreneurship. Levie and Autio (2008) delineate nine entrepreneurship conditions that support an institution's entrepreneurship (finance, government policy, government entrepreneurship programs education, R&D transfer, commercial and legal infrastructure, entry regulation, physical infrastructure, cultural and social norms). All these entrepreneurship conditions stand as formal pillars within the institutionalization of women entrepreneurs. Actionable and drastic changes should be strategized within a country's institution. Thus, opportunities can be created for potential women entrepreneurs by determining and reshaping the prospects of entrepreneurial activities and removing significant barriers to market entry (Yousaffzai *et al.*, 2015). Apart from the formal institution, challenges faced by women entrepreneurs mainly originated from the informal institution, coming from society's failure to recognize and acknowledge their contribution (Shastri *et al.*, 2019). Based on Brush *et al*.'s (2009) gender-aware framework for women's entrepreneurship around "3Ms" (market, money, and management), the institutional environment can be rejuvenated by incorporating social capital theory that would strengthen the fundamentals of women networking in the form of trust, network ties, and shared vision.

Women's entrepreneurship is primarily linked to the sustainable development goal (SDGs). Specific attention has been envisioned to foster women's empowerment while at the same time vying for the SDGs (Karki & Xheneti, 2018; Chakraborty & Biswal, 2021). Strengthening women entrepreneurs in achieving the SDG would result in gender parity, social equilibrium, and poverty alleviation. Women's participation in the economy would enable a clear pathway towards achieving the SDGs (Strawser *et al.*, 2021). Specifically, the promotion of women's participation in entrepreneurship is vital for achieving SDG 1, which aims to end poverty in all its forms everywhere, so many have called for the promotion of women entrepreneurship (Quagraninie *et al.*, 2020; Okolie *et al.*, 2021). Developing countries have received greater attention and face more challenges in achieving the SDGs, especially due to the prominent gender gap. Furthermore, there is a lack of opportunities for women in the labour market, including self-employment (Karki & Xheneti, 2018). A key argument in support of women lies in 'empowerment formalization,' which encompasses business training, access to finance and networks, and supportive mechanisms (Karki & Xheneti, 2018). Such informal and formal empowerment integration would be a more accessible pathway towards achieving the SDGs. The opportunities to involve women entrepreneurs would lead to impactful growth for the developing nations, which – along with the developed counterparts – pledge to achieve the SDGs. The UN's SDGs are by far the best frameworks to achieve social equality (Strawser *et al.*, 2021). The fulfilment of the SDGs relies on the active involvement of women in the economy, particularly in entrepreneurship, as it can foster and amplify value creation among people.

CONCLUSIONS

This review proposes three practical implications for strengthening women entrepreneurs in developing countries. Firstly, employability and empowerment are vital components in moulding women entrepreneurs to set new goals and push boundaries for tremendous success. Empowering women has been a global topic, leading to the implementation of many initiatives and programs. Direct aid to women entrepreneurs should be provided through microfinance programs to empower them (Hussain *et al.*, 2018). It has been hailed as means to alleviate poverty among women, providing financial exclusion of women's involvement, and empowering them in society (Naser & Crowther, 2016). Microfinance or microcredit ensures that poor and deprived women can access essential financial services through a collateral scheme. Furthermore, it is believed to be an effective measure to address the 'feminization of poverty' (Tariq *et al.*, 2020).

An example of a microcredit program that was implemented in such a way to uplift individuals at the 'bottom of the pyramid' was implemented in India known under the name Pradhan Mantri Mundra Yojana (Sahu *et al.*, 2021). The study confirmed that microcredit schemes have enormous potential to empower women and generate employment. Rather than implementing a debt collection concept, the microfinance concept and structure can be constructed in gender collaboration within the entire microfinance industry instead of aiming only at the poor and vulnerable women. Microfinance institutions should introduce proper staff performance indicators rather than pressure collection, an incentive scheme that would help to develop social development among women entrepreneurs (Naser & Crowther, 2016). Stakeholders and policymakers should introduce a special program or initiative with a comprehensive policy to transform and elevate women's entrepreneurship status. Institutionalizing microcredit programs through a policy of inclusion has been shown to lead to a high rate of repayment among women entrepreneurs (Drori *et al.*, 2018). These microfinance initiatives would help elevate local women's quality of life and the country's economic development (Yousfani *et al.*, 2019).

Women entrepreneurs need to be more resilient than before in today's competitive environment. Before providing women with specific courses or programs to develop their entrepreneurship skills and values, it is essential to develop a comprehensive protective measure to strengthen their mental health and resilience (Badzaban *et al.*, 2021). Resilience enables individuals to confront adverse and hostile challenges, navigate through destabilizing circumstances, and ultimately emerge as stronger individuals. Within entrepreneurship, the ability to bounce back from hardship and adversity is referred to as entrepreneurial resilience (Quagrainie, 2020). Policymakers and stakeholders

are advised to consider the development of women-focused psychology programs to help build resilience and enable women to grow individually by recognizing and realizing their talent and capabilities. Resilient entrepreneurs can overcome abrupt changes, take advantage of new environments and learn from mistakes quickly (Welsh *et al.*, 2018b).

Finally, the current entrepreneurship curriculum is inadequate to produce successful entrepreneurs, including men. Most entrepreneurs were developed through informal instead of formal education (Mohamad *et al.*, 2015). Empirical studies show that there is no correlation between entrepreneurship education and business performance or the practical way of doing business (Orobia *et al.*, 2020; Cho & Lee, 2018). The current entrepreneurship education at the higher education level does not directly influence individual engagement in business sustainability activities (Orobia *et al.*, 2020). Informal entrepreneurship education was more effective in influencing graduates to participate in entrepreneurship activities (Mohamad *et al.*, 2015). As such, attentive measures should be constructed to integrate a specific campus-wide application to encourage young women in higher education. A significant initiative must be addressed through practical in-campus experience to empower female students to imbue the mentality of becoming entrepreneurs. The Malaysian University education system showed an example through its 'women in social entrepreneurship program' (Sengupta & Sahay, 2017). Such formal and informal integrated programs would build a basic understanding of specific entrepreneurship while building up the resilience of future women entrepreneurs. This task should be embraced by relevant parties, including academics, industry practitioners and policymakers, that can contribute towards elevating women entrepreneurs within a complex and sophisticated modern society.

Limitations and Future Studies

This study possesses several limitations. Firstly, the bibliometric analysis may suffer from biases, such as language biases, self-citation and institutional bias (Bullock *et al.*, 2018). Older articles may have received more citations in comparing publications of influence as they have been long in the public domain compared to recent articles. New articles require several years to accrue citations, and thus their influence may only be seen in later stages. Secondly, the inclusion of the first author in the cited-based analysis (citation and co-citation) is also a limitation, because multiple first authors may have co-authored other influential articles that are not adequately represented in the analysis. To overcome such issues, future studies could perform a systematic literature review and meta-analysis approach that can provide different perspectives based on the current topic. These two analyses would cater for the limitation in bibliometric analysis and present a holistic knowledge of women's entrepreneurship in developing countries.

Future research should look into women's leadership perspectives within the entrepreneurship landscape. The topic of leadership in entrepreneurship and women leadership in developing countries is an intriguing subject in the twenty-first century as both would either support or diminish society's potential pursuant to opportunities and talent (Maheshwari & Nayak, 2020). The interface of these two intellectual areas serves as an untapped area for future research (Reid *et al.*, 2018; Pollack *et al.*, 2020). In the same vein, society's expectation of women's potential limits their progress to top managerial and ownership levels despite being successful on merit and possessing equal education and career progression (Azeem *et al.*, 2021). Scholars should look into how women can become leaders in their entrepreneurial pursuit, especially in medium size to big corporations that would mend the stereotype and scepticism on the potential and capabilities of women, diminishing gender discrimination in developing and emerging countries.

This review captures the knowledge structure from the bibliometric approach by providing a state-of-the-art analysis based on the structure of the past, current, and future trends in women's entrepreneurship in developing countries. The study identified the most significant publications that provide a fundamental reference in the subject. The co-citation analysis produced four clusters 1) differences between men and women entrepreneurs, 2) development of women's entrepreneurship, 3) challenges among women entrepreneurs in developing countries and 4) progress in women's entrepreneurship studies that specify the current fundamental knowledge structure in women entrepreneurs. Finally, the co-word analysis helps foresee potential works in women's entrepreneurship in the future. The four

clusters include 1) innovation in women's entrepreneurship, 2) self-efficacy and performance, 3) empowerment of women entrepreneurs and 4) self-employment and assistance to women entrepreneurs. Specifically, policymakers can do little to address the constraints in women's entrepreneurship, contributing to complex social structures. Nevertheless, vocal support for women's rights and the fight for equality should be progressively attended. Through continuous efforts within the government and corporations towards women, they can contribute even more to the country's economic development.

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Is there more to compensation than money? The empirical study of dimensionality of the total rewards model and its implications for entrepreneurship

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A B S T R A C T
Objective: We aim to verify the dimensionality of the total rewards (TR) model, the idea that employees' compensations do not consist only of money but encompass all financial and non-financial values that employees received from their work.
Research Design & Methods: Drawing inspirations from three influential TR models and using data from a large multi-occupational online survey, we conducted exploratory factor analysis (FA) (n = 3022) to test TR dimensionality and structural equation modelling (SEM) (n = 2641) to test TR validity.
Findings: The FA results revealed the two-dimensional structure of TR as best fitting to data, showing financial (tangible) and non-financial (intangible) rewards as two distinct aspects of compensation. The SEM analysis showed specific patterns of associations for each TR dimension with employee loyalty, motivation, intention to quit, and organizational performance.
Implications & Recommendations: The success of an entrepreneurial firm might depend not only on innovation in products and services but also on innovative compensation that allows for gaining competitive advantages. The TR model might be used to address these challenges and build a competitive workforce by attracting talented employees from the labour market even under financial resources scarcity.
Contribution & Value Added: By showing the role of intangible rewards in compensations, our findings might inspire further entrepreneurial research and provide entrepreneurial firms with the conceptual device to design compensation systems that accumulate human capital not only by money but also via intangible rewards.

Article type:	research article
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INTRODUCTION

The total rewards (TR) model (Armstrong, 2010; Milkovich, Newman, & Gerhart, 2014; WorldatWork & Cafaro, 2021) assumes that financial profits are not the sole rewards that people received from their work. Instead, employee compensation includes every tangible and intangible gain that arises as a result of work that might be considered by employees as a value. From the common-sense perspective, it is pay (*i.e.* money) that attracts, motivates, and keeps employees in the firm, but from the TR model perspective, the intangible aspects of work (*e.g.* job challenges) are also important. As the TR model might provide insights into the perception of work rewards and the design of compensation structure in every organization, it is particularly useful in the context of entrepreneurship as by adopting the TR model view that compensation is not only money, we might gain a better understanding of entrepreneurial firms. Although there are many definitions of the entrepreneurial firm, in this article we refer

to entrepreneurial firms as firms undertaking entrepreneurial activity where according to the OCED entrepreneurial activity might be defined as 'the enterprising human action in pursuit of the generation of value, through the creation or expansion of economic activity, by identifying and exploiting new products, processes or markets' (Ahmad & Seymour, 2008, p. 14), thus an entrepreneurial firm is an organization that mainly aims to generate value by creating and implementing innovations and in this context the idea of TR is particularly important. Firstly, from the beginning, innovative entrepreneurial activity is a high-risk activity (Shepherd, Douglas, & Shanley, 2000) and yet another struggle for entrepreneurs is how to competitively compensate employees when financial resources are scarce. The TR model suggests that entrepreneurial firms might highlight intangible aspects of work as an aspect of employee compensation. Non-entrepreneurial competitors as mature and profitable organizations might pay more in terms of money (tangible rewards) but usually do not provide such an interesting or challenging job environment (intangible rewards) as an entrepreneurial firm. Secondly, with increased skilled labour shortages and war for talents, entrepreneurial firms might search for exceptionally talented employees that already are working for other companies and are highly paid for their competencies, thus the challenge is how to convince talents to join an entrepreneurial firm. To this end, the prospect theory value function (Kahneman, Tversky, 1979), describing how people might react to increases in pay levels, shows that the value assigned to pay has decreasing effects the more is gained. This suggests that intangible rewards from TR models might become a token of importance in attracting talented employees (Holland, Sheehan, & De Cieri, 2007; Aguinis, Gottfredson, & Joo, 2012). In other words, talented employees might not be convinced to join an entrepreneurial company because their current monetary rewards are already on a high level, but they might be attracted by intangible rewards such as e.g job autonomy or new challenges that might be on a low level in their current workplace. Finally, entrepreneurial firms often look for a specific profile of innovative employees. Such employees might be attracted by intangible rewards (*e.g.,* a firm's mission) rather than only by tangible ones (Klarner, Treffers, & Picot, 2013; Moser, Tumasjan, & Welpe, 2017). Thus, a compensation policy built on the TR model that highlights a proper mix of financial and non-financial rewards might – according to the sorting effect of compensation (Cadsby, Song, & Tapon, 2007) – attract employees that build a desirable structure of the human capital in the entrepreneurial firm.

However, although TR is a popular conceptual model and compensation tool, the idea of TR is vague, lacks theoretical underpinnings, and is often used as an umbrella term. There is a lack of clarity on the structure and components of TR. Therefore, our study aims to contribute to filling the existing gap in the literature by providing a clearer and more comprehensive understanding of the components that make up TR. We aim to advance management knowledge by putting forward the proposition of an empirically verified structure of TR and in doing so, we made a first step towards standardizing the understanding of TR, which represents a significant advancement in developing TR and establishing a more robust model of the evidence-based structure of TR. Our study challenges our current understanding of TR as a vague concept and might advance management knowledge by establishing TR's structure. Moreover, as the TR model is universal and might be adopted by every organization, we highlight the impact of the TR framework on entrepreneurial organizations, where non-financial rewards can play an essential role. We see the important contribution of a better understanding of TR in the entrepreneurial context for at least three reasons. Firstly, TR highlights the importance of non-financial rewards as complementary to monetary compensation, which is crucial for entrepreneurial firms often limited in financial resources. This highlights the potential for paying employees with intangible rewards such as growth opportunities, autonomy, and changes in their roles. Secondly, TR can aid in attracting talented employees from other companies by offering better non-financial rewards, even if the firm cannot compete financially. Thirdly, a thorough understanding of TR can help build a workforce that is motivated not only by financial incentives but also by the possibility of being creative and innovative. Therefore, our study provides general insights into the TR model, these insights are especially important for entrepreneurial companies facing financial constraints, as they need to understand the full range of employee rewards beyond monetary compensation. By leveraging the knowledge of TR's structure, entrepreneurial firms can develop human capital-enhancing strategies to attract and retain talented employees, even if they cannot offer competitive salaries. This approach

can ultimately contribute to the success and sustainability of entrepreneurial ventures. The first part of our article provides a concise literature review, focusing on three influential Total Rewards models that played a crucial role in formulating our research question. Building on this, we proceed to outline the analytical strategy adopted in our study, followed by the presentation of the empirical results. Finally, we discuss our findings in light of the Total Rewards theory and present both practical implications and theoretical contributions of our paper.

LITERATURE REVIEW

As the idea of TR is appealing in entrepreneurial practice, it is still neglected in entrepreneurship research. The TR concept was developed around 1990 but gained most of its recognizability 10 years later (Giancola, 2009). Today it seems to be very popular in the current business environment with Total Reward Specials positions across organizations and with leading consulting firms providing their services in variations of different TR frameworks (see *e.g.* Aon, 2023; EY 2023; PWC, 2023; KPMG, 2023; Deloitte, 2023). However, despite its popularity, a more robust understanding of the TR model in scientific literature is still limited. More importantly, it is still not clear how many dimensions the TR model should have, what type of rewards it should include, or what are correlates of different TR dimensions. To describe this ambiguity around current TR models we present a detailed analysis of three, influential TR theoretical approaches. Although, as we mentioned, there are different approaches to TR models (see Jiang, Xiao, Qi, & Xiao, 2009; Nazir, Shah, & Zaman, 2012), we decided to concentrate on three models that are most influential according to our judgment and practical experience. Firstly, we focused on WorldatWork model, which is developed by a leading association of TR practitioners and is used globally to attract, motivate, engage, and retain valuable employees. Secondly, we moved to Armstrong's TR models. Armstrong is a leading scholar and global expert in HR management and his book on rewards (Armstrong, 2010) that describes his view of TR is very popular among practitioners and has about 450 citations in the scientific literature (based on Google Scholar). Thirdly, we focused on Milkovich, Newman, and Gerhart's book *Compensation* (2014), which describes their model of 'total returns' and is a classic handbook known to every compensation specialist. Its influence is best illustrated by the fact that it already has 12 editions and in scientific literature it has about 3690 citations.

The first influential approach to TR is the one by WorldatWork (2023). According to it, TR is 'the monetary and nonmonetary return provided to employees in exchange for their time, talents, efforts, and results' (WorldatWork, 2012, p. 4). It also distinguishes five main categories of rewards: compensation, benefits, work-life, performance and recognition, development and career opportunities (WorldatWork, 2012). WorldatWork's idea of TR is continuously evolving and in the 2021 edition, the five domains of TR are compensation, well-being, benefits, recognition, and development (see WorldatWork, 2021; WorldatWork & Cafaro, 2021, p. 12).

Milkovich, Newman, and Gerhart (2014) use the label total returns to describe all variations in rewards that people received from their work. Total returns are split into two categories, namely total compensation and relational returns. Relational returns include returns that are more elusive and psychological in nature *e.g.* recognition and status, employment security, work challenges, and learning opportunities. Meanwhile, total compensation is seen as transactional and more tangible and according to Milkovich, Newman, and Gerhart (2014), this category of returns might be further split into two subcategories of cash compensation, namely pay received directly in the form of cash and benefits and pay received indirectly in the form of various valuable goods but not cash. Cash compensation includes such components as *e.g.*, based pay, cost-of-living adjustments, short-term incentives, and long-term incentives. The benefits include *e.g.*, income protection, pensions, medical insurance, work-life balance programs, and allowances.

Armstrong (2010, p. 35) defines TR as 'the combination of financial and non-financial rewards available to employees' and distinguishes two major categories of TR, namely transactional rewards and relational rewards. Transactional rewards are financial, extrinsic rewards resulting from reciprocal exchanges of goods between an employee (who provides her/his time, effort, and competencies) and an employer (who provides rewards). According to Armstrong (2010), transactional rewards include base

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pay, contingent pay, and employee benefits. In contrast, relational rewards are composed of a mix of intrinsic and extrinsic non-financial rewards, this category includes experience with the work environment, non-financial recognition, performance management, and learning and development. The graphical summary of the three mentioned approaches to TR is presented in Figure 1, which also illustrates that using these three models of TR allows us to capture a diverse pool of possible work rewards.

Figure 1. Three influential approaches to the total rewards model
Source: own elaboration based on: Milkovich, Newman, and Gerhart (2014),
Armstrong (2010) and WorldatWork and Cafaro (2021).

The three TR frameworks in Figure 1 provide some different underlying theory about the nature of workplace rewards from the TR perspective. Milkovich, Newman, and Gerhart (2014) and Armstrong (2010) suggest that rewards might be generally separated into two broad categories of transactional (financial) and relational (non-financial) rewards, whereas WorldatWork (2021) does not follow this two-dimensional distinction but refers to five broad categories (WorldatWork & Cafaro, 2021). Next, Milkovich, Newman, and Gerhart (2014) differentiate financial reward into the category of direct pay-cash and indirect pay – bonuses, whereas Armstrong (2010) puts direct and indirect pay into only one financial category. From the three presented TR frameworks only Milkovich, Newman, and Gerhart (2014) mentioned employment security as a reward. Armstrong (2010) refers to performance management as a

reward and WorldatWork (2021) – as a reward including well-being. This illustrates the confusion in the understanding of TR that might limit the possibility of successfully using this approach in the entrepreneurial context. Therefore, the study aims to verify the dimensionality of the TR model, the idea that employees' compensations do not consist only of money but encompass all financial and non-financial values that employees received from their work. Thus, the research question we want to address is:

RQ: What is the structure of rewards in the TR framework?

By verifying the structure of the TR model, we might (i) explore the patterns of employee perception of work rewards (ii), distinguish rewards categories based on empirical rather than normative analysis, and (iii) based on this, highlight the important role of non-financial reward in compensations policy of entrepreneurial firms.

As there is a lack of theoretical justification for a prior hypothesis about TR dimensionality *i.e.* at the current stage of research, in our judgement, there is no theoretical rationale to assume that some model of TR is more valid than others. Thus our study has an exploratory character and we only provide a research question but not an a priori hypothesis that needs robust theoretical support (Scheel, Tiokhin, Isager, & Lakens, 2021). To this end, we used exploratory factor analysis (EFA) on a large sample from multi-occupational online survey to explore the dimensionality of rewards perceptions. Then, to test the validity of TR structures obtained in EFA, we analysed the nomological network (see Cronbach & Meehl, 1955) of relationships between TR dimensions and work motivation, organizational performance, employer loyalty, and quit intention using the structural equation modelling (SEM) approach.

RESEARCH METHODOLOGY

Procedures

To analyze the dimensionality and structure of TR perception, we used data obtained from Sedlak & Sedlak job satisfaction survey (n = 3493). The available dataset was collected between June and September 2020. Sedlak & Sedlak used non-probabilistic sampling methods combining accidental and target sampling. Firstly, the research was promoted among the company's web page users. Then after sample analysis and identification of underrepresented groups target sampling was used through social media targeted advertisement. It has to be said that Sedlak & Sedlak runs the biggest salary portal in Poland and two other web pages connected with the labour market. Such a sampling method is efficient having in mind the input cost and output quality ratio. The data collection process included manual data cleaning procedures. For example, respondents who finished the survey unreasonably fast (at least 30% faster than the authors of the tool) were excluded. There was also a qualitative assessment of outlier cases performed based on a judgment of data analysts employed by Sedlak & Sedlak.

Participants

In the final data sample, there were 37.5% of women (1310 cases) and 62.5% of men (2183 cases). The youngest respondent was 18 years old, the oldest 81, and the mean age was M = 37 (SD = 9; Q1 = 30, Q3 = 43), 24.6% of the sample were employed in companies with the employment of 50 or less; 24.7% in companies employing between 51 and 250 people and 50.6% worked in bigger organizations. In the sample, there were 79.4% of people with higher education.

Measures

In a database available from the Sedlak & Sedlak job satisfaction survey, we identified items relevant to the rewards perceptions from the point of view of the three popular TR frameworks, that is, Milkovich, Newman, and Gerhart (2014), Armstrong (2010), and WorldatWork (2021). Items from Sedlak & Sedlak survey used to represent TR dimensions are presented in Table 1 along with information on which TR framework was a source of its inclusion. The answers to these items were provided on a 5-point scale from -2 to 2 (participants saw only labels from strongly disagree to strongly agree), descriptive statistics for all items are presented in Table 2.

Table 1. Items from Sedlak & Sedlak job satisfaction survey used to measure total rewards

Item	Presumed total reward (TR) dimension in three popular TR frameworks		
	Milkovich, Newman, and Gerhart (2014)	Armstrong (2010)	Worldat-Work (2021)
You are satisfied with received additional benefits.	Benefits	Benefits	Benefits
You are satisfied with your total pay if you compare it to the market wage for a similar job.	Cash	Compensation	Compensation
Your salary is appropriate to the duties you perform.	Cash	Compensation	Compensation
You are satisfied with your total salary.	Cash	Compensation	Compensation
The duties entrusted to you by your direct supervisor are interesting.	Challenging work	Learning and development	X
Your job gives you the opportunity to challenge yourself with different tasks.	Challenging work	Learning and development	X
The company gives you a feeling of employment security.	Employment security	X	X
The company provides you with development opportunities.	Learning opportunities	Learning and development	Development
The trainings provided by the company helped you to develop your skills.	Learning opportunities	Learning and development	Development
You still learn something new at your current job.	Learning opportunities	Learning and development	X
Your immediate superior appreciates your work.	Recognition	Non-financial recognition	Recognition
You feel appreciated at work.	Recognition	Non-financial recognition	Recognition
You have a real possibility of promotion.	X	Learning and development	Development
You like your job.	X	Work experience	Well being
You feel satisfied with your professional life.	X	Work experience	Well being
You feel an emotional bond with your company.	X	X	Well being
You receive feedback regarding your work.	X	Performance Management	X
There is a fair salary system in the company.	X	Performance Management	X
There's an atmosphere of cooperation in the company.	X	Work experience	X

Source: own elaboration.

Validity Tests: Nomological Network Using SEM

To test the validity of the TR dimensionality that will emerge from the EFA, we tested its nomological network using the structural equation modelling (SEM) approach. In this approach, to establish factor structure validity we first had to establish valid factors in EFA and show that these factors have expected patterns of associations with other important variables, meaning that they form distinct nomological networks. For example, if we find the three-factor structure of TR in EFA and all these three factors have the same patterns of associations with important organizational outcomes, this raises a question of three factorial validity structures: If all dimensions predict the same variables in a similar way, what have we learned from having three dimensions?

Table 2. Means, standard deviations, and the number of cases for total rewards items used in this study

Item	M	SD	N
You are satisfied with your total salary.	-0.22	1.29	3487
You are satisfied with your total pay if you compare it to the market wage for a similar job.	-0.15	1.27	3455
Your salary is appropriate for the duties you perform.	-0.30	1.27	3467
You are satisfied with received additional benefits.	-0.20	1.34	3287
Your immediate superior appreciates your work.	0.47	1.19	3407
You like your job.	0.81	1.02	3485
You feel satisfaction with your professional life.	0.19	1.18	3482
You feel an emotional bond with your company.	0.18	1.20	3463
There's an atmosphere of cooperation in the company.	0.54	1.07	3485
There is a fair salary system in the company.	-0.35	1.21	3271
You receive feedback regarding your work.	0.15	1.19	3447
Your job gives you the opportunity to challenge yourself with different tasks.	0.64	1.09	3463
You have a real possibility of promotion.	-0.48	1.23	3349
You still learn something new at your current job.	0.48	1.21	3485
The training provided by the company helped you to develop your skills.	-0.18	1.35	3275
The company gives you a feeling of employment security.	0.93	1.07	3484
You feel appreciated at work.	0.06	1.24	3469
The duties entrusted to you by your direct supervisor are interesting.	0.31	1.08	3397
The company provides you with development opportunities.	0.08	1.22	3456

Note: A different number of responses for different variables when calculating descriptive statistics comes from respondents choosing the answer 'I do not know,' which does not apply and thus was treated as missing data and excluded from the analysis.
Source: own elaboration.

To test the validity of the result of factor analysis in SEM, we included four criterion variables, namely performance, loyalty, intention to quit, and motivation. These variables were created based on appropriate Sedlak & Sedlak job satisfaction survey items. On all these items except loyalty, respondents answered on a 5-point scale from -2 to 2. Descriptive statistics for all these measures are presented in Table 3 and all measures are described in detail below. Self-assessed performance of organization represents employee evaluation of organizational performance, sample item: 'Company provides customers with products/services of good quality.' Cronbach's alpha was 0.860. Employee loyalty was measured with employee net promoter score (eNPS) measured with a single item: 'How likely is it that you would recommend the work in your current company to a friend or colleague? On a scale from 0 to 10 (where 0 means not at all likely and 10 – extremely likely).' Intention to quit reflecting employee detachment from work was measured with a single-item question: 'You often think about changing your job.' Employee work motivation represents the subjective feeling of being motivated to a job by the organization and was measured with a single item: 'You feel well motivated to work' (see Allen, Iliescu, & Greiff, 2022 for a discussion of the legitimacy of single-item measures).

Table 3. Mean, standard deviations, and correlations between the criterion variable

Criterion variable	M	SD	1.	2.	3.
1. Organization Performance	0.55	0.76	X	X	X
2. Loyalty (eNPS)	5.80	2.91	0.761**	X	X
3. Quit intention	0.15	1.30	-0.547**	-0.641**	X
4. Motivation	-0.18	1.19	0.648**	0.689**	-0.659**

Note: eNPS = employee net promoter score, *** $p < 0.001$
Source: own elaboration.

RESULTS AND DISCUSSION

We conducted factor analysis (Hair, Black, Babin, & Anderson, 2014; Watkins, 2018) to explore the dimensionality of employees' TR perception and to verify to what extent this structure is different or

congruent with the normative view presented in the literature (Milkovich, Newman, & Gerhart, 2014; Armstrong, 2010; WorldatWork, 20012; 2021). We implemented the principal axis factoring extraction method with promax rotation to explore the factorial structure of 19 TR items described previously in Table 2. Our data had a good fit for exploratory factor analysis as confirmed by Bartlett's test of p < 0.001 and Kaiser–Meyer–Olkin (KMO) measure of 0.946. At first, to explore TR dimensions, we used a criterion of eigenvalues higher than one and we conducted a visual inspection of factor analysis scree plots (Hair *et al.*, 2014). Based on this, in our data (*i.e.* 19 items from Table 2 and N = 2784, after missing data listwise deletion), there emerged three factors with an eigenvalue higher than 1, factor 1 8.91; factor 2 1.84 and factor 3 1.03. However, factor 3 had an eigenvalue only slightly higher than the threshold of one and one item 'You like your job' had a particularly strong load (0.931) on this factor. After the deletion of this item and repeating the analysis on 18 items (N = 2786), we obtained two factorial structure according to the criterion of eigenvalues higher than one. Then inspection of the EFA results revealed some problematic items. Two items 'You are satisfied with received additional benefits' and 'The company gives you a feeling of employment security' had factor loadings lower than 0.5 as this value is generally considered necessary for practical significance (see Hair *et al.*, 2014). Three items 'Your immediate superior appreciates your work,' 'There is a fair salary system in the company,' and 'You feel appreciated at work' have cross-loading, a factor loading of similar weight on both factors, thus these five items were deleted and we repeat analysis on 13 items (N = 3022) obtaining a final two factorial structure with 10 items on factor 1 (0.45 explained variance) and three items on factor 2 (0.11 explained variance) as presented in Table 4. Based on the substantive content of each factor, we labelled factor 1 as non-financial (relational) rewards. Because it consists of intangible rewards such as development or a positive emotional bond with the job. Whereas factor 2 was labelled as financial (transactional) rewards, because these factor items represent tangible reward that refers to an exchange transaction between employee and employer *i.e.* appropriate pay in return for the job efforts. To further test the robustness of these two factorial structures, we also conducted a confirmatory factor analysis using maximum likelihood estimation, obtaining fit indices as; RMSEA = 0.084; 95% CI [0.080 – 0.088] SRMR = 0.042; CFI = 0.94, although not perfect, they were acceptable, particularly for an exploratory study. Moreover, after inspection of model modification indices, we identified two items with particularly strong error terms correlations. These were 'the company provides you with development opportunities' and 'the training provided by the company helped you to develop your skills.' After adding this correlation to a model, we observed the improvement in fit indices: RMSEA = 0.074; 95% CI [0.070 – 0.078] SRMR = 0.039; CFI = 0.96. Therefore, when considering factor analysis results and the substantive meaning of the factors, the two-factor solution might be seen as representing the general theoretical division of TR into financial (transactional) and non-financial (relational) rewards that are the two most general categories in both most influential TR models of Milkovich, Newman, and Gerhart (2014) and Armstrong (2010).

Next, to test the validity of obtained factors in the SEM model, we created two variables. The first one representing non-financial rewards was calculated as a mean value from 10 items from factor 1, and similarly, for the financial rewards, we calculated a mean value from three items from factor 2 (see Table 4). Although there are many approaches to factor score calculations based on factor analysis results (see DiStefano, Zhu, & Mindrila, 2009), we chose this simplest approach, *i.e.* calculating the arithmetic mean from all items taped into each factor, which might be also called a summated score approach (see Hair *et al.*, 2014), as this approach is recommended in exploratory analysis and is practically feasible and easy to calculate and understand in practical settings.

This results in two variables, financial rewards M = -0.23 (SD = 1.20); median = -0.33 and non-financial rewards M = 0.19 (SD = 0.85); median = 0.20, (a -2 to 2 scale). For financial and non-financial rewards factors, Cronbach`s alpha was very high, *i.e.* 0.938 and 0.898 respectively, suggesting its high internal consistency of created scales. To test the validity of the two-dimensional solution, we tested relationships between financial and non-financial rewards and four criterion variables: performance, loyalty, intention to quit, and motivation. To this end, we created a structural equation model in which the non-financial and financial rewards were used as predictors of criterion variables. We used JASP software with maximum likelihood estimations. In this complex model, we used 2641 observations without missing values

in variables of interest. To check the robustness of this approach, we repeated estimation using the JASP FIML build-in imputation of missing values method to impute values for those that were missing, thus obtaining similar model parameters. The created model is presented in Figure 2.

Table 4. Mean, standard deviations, and correlations between the criterion variable

Item	Factor 1 Non-finan-cial rewards	Factor 2 Financial rewards
The company provides you with development opportunities.	**0.842**	0.018
You still learn something new at your current job.	**0.801**	-0.090
Your job gives you the opportunity to challenge yourself with different tasks.	**0.760**	-0.080
The duties entrusted to you by your direct supervisor are interesting.	**0.739**	-0.040
You feel satisfaction with your professional life.	**0.721**	0.101
The training provided by the company helped you to develop your skills.	**0.616**	0.001
You have a real possibility of promotion.	**0.613**	0.099
You receive feedback regarding your work.	**0.607**	0.062
There's an atmosphere of cooperation in the company.	**0.552**	0.080
You feel an emotional bond with your company.	**0.551**	-0.031
You are satisfied with your total pay if you compare it to the market wage for a similar job.	-0.028	**0.932**
Your salary is appropriate for the duties you perform.	0.011	**0.863**
You are satisfied with your total salary.	0.000	**0.951**

Note: n = 3022, Extraction Method: Principal Axis Factoring, Rotation Method: Promax, bolded are items with factor loadings higher than 0.50
Source: own elaboration.
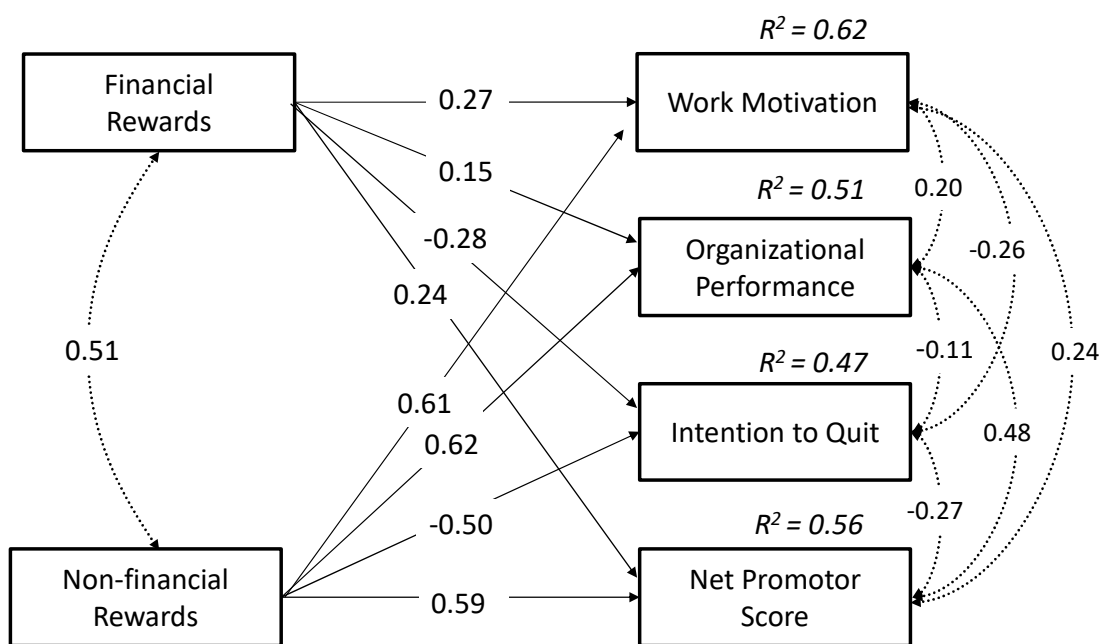
Figure 2. Structural equation model of relationships between financial and non-financial rewards and four criterion variables used to test the validity of two factorial total rewards model
Note: Model estimated in JASP software with maximum likelihood estimation method. Numbers on the solid line represent standardized regression weights, numbers on the dotted line represent correlations, all coefficients have p < 0.001
Source: own elaboration.

Based on the model depicted in Figure 2, firstly, we tested the validity starting from the correlation between financial and non-financial rewards of about r = 0.51, p < 0.001, R^2 = 0.26 suggesting that these two factors represent related but distinct constructs. Although the two rewards dimensions were significantly related to each other at the same time they shared only about 26% of the common variance. Second, in Figure 2 we might notice that financial and non-financial rewards have different patterns of relationships with criterion variables, where relationships, as expressed by

standardized regression weights for non-financial rewards, are about two times stronger than for financial rewards. Moreover as can be seen in Figure 2 employees' perceptions of their financial and non-financial rewards are significantly related to the criterion variables reflecting aspects of human capital, as expected we might predict the level of work motivation ($R^2 = 0.62$), intention to quit ($R^2 = 0.47$), employee assessment of company performance ($R^2 = 0.51$) and employee loyalty to the employer ($R^2 = 0.56$) based on financial and non-financial rewards perception. To check the robustness of our model we also retest it using the latent variables approach, i.e. we replicate our SEM analysis but we do not use summated scores to represent financial and non-financial rewards, but we use latent variables (as the measurement model obtained in the previous CFA suggest, we correlated errors terms for items 'the company provides you with development opportunities' and 'the training provided by the company helped you to develop your skills'). We obtained almost identical results as previously, with even sharper distinctions between roles of financial and non-financial rewards. Consequently, the standardized regression weight (β) for financial and non-financial rewards were, for organizational performance $\beta = 0.10$; $\beta = 0.67$; for NPS $\beta = 0.19$; $\beta = 0.64$ for work motivation $\beta = 0.21$; $\beta = 0.68$, and for quit intentions $\beta = -0.24$; $\beta = -0.55$. Meanwhile, SEM model fit indices were as follows; RMSEA = 0.075; 95% CI [0.072 – 0.078] SRMR = 0.038; CFI = 0.95, thus suggesting not perfect but acceptable fit of our latent variable SEM model. Therefore, in general, the structural model presented in Figure 2 seems to support the validity of the two factorial structures of TR.

Discussing our results and referring to prior research on TR (Milkovich, Newman, & Gerhart, 2014; Armstrong, 2010; WorldatWork, 2012), our findings suggest that although we have various multi-dimensional conceptual models of TR in literature (see Jiang *et al.*, 2009; Nazir, Shah, & Zaman, 2012), the two-dimensional division on financial and non-financial rewards might be most valid based not only on conceptual but empirical analysis. This seems to be also in line with previous findings from career success literature, showing that objective *e.g.* financial and subjective *e.g.* non-financial success are not always interrelated (Abele & Spurk, 2009). By focusing our attention on the fact that employee perception of work rewards is two-dimensional, the results of this study might help understand employee reactions to work rewards and better design compensation policies stimulating human capital. The two-dimensional TR model established in this study might operate in every organization but as we discussed previously, in our view, it might be particularly impactful in the context of entrepreneurial firms. In entrepreneurial firms, success might depend not only on innovation and creativity in products or service development but also on the firm innovation in compensation, the ability to create an innovative compensation scheme that allows for gaining competitive advantages under the scarcity of financial resources. In this case, the TR model of tangible and intangible rewards might be a viable option for attracting talented employees from the labour market and using the compensation sorting effect to build the desired structure of the workforce. Moreover, attention to dimensions of employee compensations might stimulate not only human capital but also the increased quality of work-life of employees among entrepreneurial firms (see Kwahar & Iyortsuun, 2018).

However, at the same time, our findings raise a baffling question of why our analysis revealed only a two-dimensional structure of work rewards. This is a counterintuitive finding in light of expectations that work rewards are complex and multi-dimensional (Milkovich, Newman, & Gerhart, 2014; Armstrong, 2010; WorldatWork, 2012). It might be difficult, particularly for practitioners, to accept that one can reduce the variety of work rewards only to two categories of financial and non-financial rewards. To this end, it is worth mentioning that a two-dimensional structure does not necessarily preclude analysis of separated reward categories. For example, in the influential Herzberg's two-dimensional model (Herzberg, 2003), we might still investigate specific hygiene and motivational factors even though we agree that on a general level, all groups fall into only two main dimensions. Similar to another influential two-dimensional model of employee well-being, *i.e.* the Job Demands-Resources model (Bakker & Demerouti, 2017), we agree that work environment characteristics might be reduced to two general factors of job demands and job resources, but this does not preclude analysis of specific demands and resources if we need this for practical or research purposes.

However, the question of why work rewards form two and not more general dimensions is worth further exploration. We would like to discuss possible explanations of this fact that might spark further debate. Firstly, although our study was inspired by influential TR models, it might not have captured enough details of various possible rewards or omitted some important rewards. Thus, it might be worth replicating with a wider pool of rewards, which might inspire future confirmatory studies. It might be also possible that even though rewards are multidimensional, employees are not able to clearly distinguish between the different aspects of rewards, which might be due to cognitive biases (Kahneman, 2011) *e.g.* hallo effect when the perception of one particular silent work reward influences cognitive evaluation of other rewards. Moreover, from the perspective of slipover theory, the perception of satisfaction from one object might be transferred to another (see Ilies, Wilson, & Wagner 2009). Thus, positive/negative experiences with one aspect of work reward might spill over to other similar rewards and thus only the two most distinct categories with clear boundaries emerge. As an exploratory survey of employees' opinions, our study might also have methodological shortcomings that might have revealed only two factors. Thus, further replication studies might use more diverse data sources *e.g.* confronting managers' and employees' views on rewards or using experimental research to conduct more objective tests and analyse not only employee declaration but also actual behaviours in response to various rewards. It might be valuable to analyse in the future what are the mechanisms behind employee judgment of work rewards.

Besides inspiring research on compensation practice in general, the two-dimensional TR model explored in this study opens promising avenues for further entrepreneurship research. Two lines of further research worth mentioning are gender discrimination in entrepreneurial firms and the behaviour of entrepreneurs. As previous studies have shown (see *e.g.* Bilan, Mishchuk, Samoliuk, & Mishchuk, 2020), gender discrimination might manifest not only in pay inequalities but also in inequalities in other aspects of compensation. Thus, the two-dimensional TR model suggests that we should pay attention to financial and non-financial aspects of work rewards when investigating discrimination in compensation practices. Gender discrimination practices might take place not only in pay levels but also in intangible rewards *e.g.*, work autonomy or work-life balance opportunities. This is particularly important because with legal regulations on pay transparency imposed by European Union (2022), gender inequalities in compensations might be moved from more visible tangible rewards (pay) to hidden intangible rewards (*e.g.* individually negotiated aspects of job autonomy) (see Wong, Cheng, Lam, & Bamberger, 2022). Especially in entrepreneurial firms in which intangible rewards might play a vital role for their innovative and creative employees, unnoticed and unjustified inequalities in access to intangible rewards might have a decrement effect on an entrepreneurial firm's human capital. Secondly, through the lens of the TR model of intangible and tangible rewards, we might try to understand the seemingly irrational behaviour of many entrepreneurs, who invest so much effort and perseverance into projects that do not bring direct financial rewards to them. The idea that compensation is not only about money but about all (often hidden and intangible) benefits that stem from work allows for a better understanding of entrepreneurs' motives. From a rational economic perspective, it might be difficult to understand why entrepreneurs are ready to invest time, effort, and money in entrepreneurial projects that do not yield financial profits during often unpredictably long time of its start-up phases or end without any financial yields. From a TR perspective, the lack of economic profit does not necessarily mean the lack of profit at all, as there might be intangible rewards even in the face of a lack of economic ones. For example, entrepreneurs might experience as rewards a feeling of satisfaction with three important human needs (Deci, Olafsen, & Ryan, 2017), *i.e.* the sense of competence (in developing challenging entrepreneurship projects), autonomy (self-defined working methods), or relatedness (to a wider entrepreneurship community). Via the lens of the TR model, these might not be the only hopes for further financial rewards that motivate entrepreneurs but also current intangible rewards that stem from the entrepreneurial activity itself. Moreover, in some situations, the intangible rewards among entrepreneurs might be more valued than financial rewards and some entrepreneurs might not be willing to scale up their business or transfer it to a more formal organizational structure, which might yield tangible financial profits at the expense of intangible rewards *e.g.*, autonomy.

CONCLUSIONS

In this study, we empirically verified the factorial structure of the TR model, the idea that employee compensation is not only built from material rewards but encompasses all values that employees receive from their work (Milkovich, Newman, & Gerhart, 2014; Armstrong, 2010; WorldatWork, 2012; WorldatWork & Cafaro, 2021). Although different models of TR are presented in the literature (see Table 1), our analysis suggests a two-dimensional structure of TR as best fitting to the data collected in this study. Factor analysis revealed two factorial structures and subsequent SEM analysis seems to confirm the validity of the two-dimensional approach. In contrast, we did not find evidence to support the more nuanced multi-dimensional approaches to TR that include more than two dimensions of rewards. The first category represents tangible financial aspects of the job, referring to the job as an economic market transaction between employee and employer. The second reward category represents a more intangible aspect of rewards one might obtain thanks to work and refer to a job not as an economic transaction but rather as a social relationship between employee and employer. From a theoretical stance, our results empirically confirm the basics of the theoretical idea of TR, showing that financial and non-financial rewards are important aspects of compensation that are associated with employee loyalty, motivation, intention to quit, and organizational performance. The findings presented in this study broaden our knowledge and provide contributions to our understanding of work rewards nature and dimensionality which might be particularly useful in entrepreneurial firms, in which efficient and creative compensation plans play a vital role in outsmarting competitors and attracting innovators. Thus, our study significantly contributes to management and entrepreneurship literature on theoretical and practical grounds. From a theoretical perspective, the study helps to understand the dimensionality of job-related rewards, which is a crucial aspect of employee-employer relationships. From a practical stance, our study provides knowledge that employees might not have as sophisticated view of rewards as we commonly believed, but in general might see work as providing two categories of rewards, *i.e.* 'pay' and 'the rest.' This is an important insight showing that instead of searching for the most important 'silver bullet' reward, employers should take care of every reward they offer employees, because dissatisfaction with one aspect of rewards might turn into a negative evaluation of the whole category. Thus, our findings provide insights that might be used for developing compensation practices and policies that suit employee needs and foster human capital development, because an understanding of the structure of work rewards expected by employees has a direct impact on compensation policy, which, in turn, can influence business performance. This endeavour is also a response to the call of Gupta and Shaw (2014) who postulated that compensation is one of the most neglected aspects of human resource management.

Our findings provide some insights but it is also important to see its limitation. As with every single study, our work cannot provide a final answer to a research question (Amrhein, Trafimow, & Greenland, 2019) and should be seen not as providing a final structure of TR but as inspiration for further debate and studies on TR. Moreover, this was an exploratory endeavour and thus needs further replications to confirm our conclusions. We used an online sample from one country and although it is large, it is necessary to make attempts to confirm our results in different cultural contexts. Moreover, we concentred on the three most influential – in our view – models of TR, and this decision is a double edge sword. On the one hand, it allowed us to justify our analytical choices and test the most influential reward categories, but on the other, we might have missed some less popular but still important reward types. Finally, we used a survey methodology and asked people about their opinions about rewards, but the question arises if people are fully aware of the impact rewards have on them. Thus, it might be important to conceptually replicate our study but with a different methodology *e.g.*, in experimental settings where objective behavioural responses to various rewards might be observed. Overall, we believe that using the TR compensation model developed in this study might open avenues for inspiring further research and contribute to management literature.

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Conflict of Interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Driving forces of informal employment:
An empirical study based on Polish enterprise data

Dagmara Nikulin

A B S T R A C T
Objective: The article aims to indicate the determinants of informal employment in registered enterprises using company-level evidence from Poland.
Research Design & Methods: The survey conducted among Polish small and medium-sized (SME) enterprises in 2018 was used to find the driving forces of informal employment in Poland. The adequate sample comprised 952 representative surveys derived from the computer-assisted telephone interview (CATI). The quantitative analysis was based on the logistic regression.
Findings: The findings indicate that among the main drivers of informal employment, one can distinguish the level of tax morality of owners or company managers and the administrative difficulties related to setting up a business. The role of non-economic factors in creating informal activities was confirmed. Moreover, informal employment was more prevalent in smaller companies operating in the construction industry.
Implications & Recommendations: Our analysis may be helpful for both research in entrepreneurship and tax evasion and the shadow economy stream. It indicates the heterogeneity among Polish enterprises related to the involvement in informal activities, particularly informal labour. Our study sheds light onto the less known dimension of 'grey activities' existing in the registered companies, which is less frequently analysed in the literature.
Contribution & Value Added: This evidence will help us understand the primary motives for using the informal workforce and enhance further research on the nature and extent of informal employment and the shadow economy in general.

INTRODUCTION

The informal sector and the broadly understood shadow economy are of interest to the scientific community and government institutions. In studies devoted to the shadow economy, one can notice a dichotomy between the formal and informal sectors, contributing to the marginalisation of hybrid phenomena occurring on the borderline of the informal zone. In other words, some informal activities might take place on the formal side of the economy. One of those phenomena is the informal employment existing in registered enterprises. This is the case for developed countries, where informal employment is from nature hidden, in contrast to developing countries where informal activities are widespread and more visible (Slonimczyk, 2022). In this article, I will describe the phenomenon of informal employment in registered enterprises in Poland as an example of a developed country. According to the yearly statistics provided by Statistics Poland, the informal economy in registered economic entities accounted for 8.5% in 2020 (CSO, 2022). Given that the shadow economy accounted for 10% of the total GDP in Poland (CSO, 2022), the contribution to the shadow economy from registered entities is significant.

At the same time, information about informal employment in registered enterprises is scarce. The existing sources for the data on informal employment in Poland (Eurobarometer survey 'Undeclared work,' Polish survey 'Unregistered work' conducted by Statistics Poland) are based on the labour market surveys and do not allow to separate informal work from the informal work existing in registered entities. Importantly, there is a need for further research due to the difficulties associated with data collection on informal employment.

To tackle informal employment, one needs to indicate reasons for it. In the existing literature, there are several approaches to explain the determinants of this phenomenon. As the problem is complex, no straightforward conclusions are provided regarding reasons for informal employment and policy measures to combat it. The most popular argument asserts that informal employment minimises or evades taxes (Bernasconi, Corazzini, & Seri, 2014). If the taxes are severe, the inclination to informal employment may be higher, as the rational actors desire to maximise their profits (Schneider, 2014). However, the emergent literature indicates that the rational economic actor approach should be replaced or/and complemented by the social actor theory (Horodnic & Williams, 2022). The rational economic actor decides on involvement in informal activities based on the calculation between the costs and benefits. In contrast, decisions made by the social actor are influenced by social factors like tax morality, peers' effects, or the social acceptance of tax evasion (Alm, Bloomquist, & McKee 2017). Nowadays, it is even claimed that non-economic social factors are becoming more and more relevant in explaining the inclination to be engaged in the shadow economy (Pickhardt & Prinz, 2014). Therefore, a holistic approach is needed to fully understand the motives for informal employment (Franic, 2022). One of the examples is the consideration of the impact of the institutional environment (Hanousek & Palda, 2004; Torgler & Schneider, 2007) and the tax morality of taxpayers (Cummings *et al.*, 2009).

This article aims mainly to fill the research gap on the determinants of informal employment in Poland. Therefore, the main goal is to indicate the factors of informal employment in Poland. Unlike previous studies, I relied on the primary data from a company managers survey conducted in 2018 among almost 1000 Polish private small and medium-sized enterprises (SMEs). I focused on SMEs as predominantly small companies, managed by individuals and operating in sectors which are less visible to tax administration, and therefore more likely to evade taxes (Putniņš & Sauka, 2015). As business owners and managers are directly responsible for paying taxes, it seems reasonable to ask them about the extent of informal employment (Torgler, 2011; Krasniqi & Williams, 2020). To the best of my knowledge, this is the first study on informal work determinants based on a company-level survey in Poland. On this background, my study's contribution to the existing literature is twofold. Firstly, I used a direct approach to measure the driving forces of informal work in Poland in registered entities. In general, most of the informal employment research is based on individuals instead of businesses or aggregate data (Putniņš & Sauka, 2015). Secondly, I extended the previous research on the determinants of informal employment. My results support the existing empirical evidence on the relationship between social and moral attitudes on the one hand and tax evasion behaviour on the other. I formulated the following research questions:

RQ1: Does the tax burden significantly impact the probability of using informal employment in enterprises?

RQ2: Could be the probability of using informal employment explained by the tax morality among company owners/managers?

RQ3: How much is the inclination to use informal employment dependent on the obstacles related to setting up a business?

Our results indicate that among the main drivers of informal employment, one can distinguish the tax morality of owners or company managers and the administrative difficulties related to setting up a business. Moreover, informal employment was more prevalent in smaller companies operating in the construction industry. The organisation of this article is as follows: introduction, literature review and hypotheses development (summarising prior research on the driving forces of informal employment), research methodology, results and discussion (presenting the results of econometric modelling), ending with conclusions.

LITERATURE REVIEW AND HYPOTHESES DEVELOPMENT

Notably, it is argued that an effective policy for reducing informal activities requires the inclusion of many aspects of tax evasion (Andreoni, Erard, & Feinstein, 1998). Accordingly, the existing empirical evidence provides a rich strand of possible explanations for informal employment. Considering the macro estimates and cross-country differences in the extent of informal work, the level of economic development, inference in a free market and state interventions, and inadequate welfare arrangements may play a role (for review see Nikulin & Sobiechowska-Ziegert, 2017).

Focusing on the determinants that explain the individual decisions on tax evasion, predominantly, it is postulated that the inclination for informal activities is purely related to the severity of taxes (see an early study from Kaplan and Reckers, 1985). Moreover, the negative impact of the tax wedge on employment is reported in the literature (Deskar-Škrbić, Drezgić, & Šimović, 2018). However, empirical evidence on taxes and informal employment is inconclusive. On the one hand, taxpayers may be more tax compliant if the tax rates are low and the tax system is perceived as fair (Mcgee & Benk, 2019) or if the perceived tax burden is high while the trust in government and the judicial system is low (Abdixhiku et al., 2017). Moreover, the tax burden may be perceived as high when people feel that taxes are used inefficiently and the tax system is excessively complex (Bazart & Blayac, 2022). Similarly, Savić et al. (2015) found that the countries with more efficient tax administration have a lower level of informal economy. Therefore, if tax rates are only considered, the relationship with tax avoidance is somewhat inconclusive (Nur-Tegin, 2008; Joulfaian, 2009; Bernasconi, Corazzini, & Seri, 2014) which implies no straightforward association between tax level and inclination to evade taxes. I formulated the first hypotheses based on this part of the literature review. All hypotheses are listed at the end of this section.

Another strand of research is devoted to social and moral determinants of tax evasion and informal activities. Nowadays, it is claimed that such non-economic social factors are becoming more and more relevant in explaining the inclination to be engaged in the shadow economy (Pickhardt & Prinz, 2014). In other words, it is widely argued that the decision to evade taxes may be related to the individual or social attitudes towards paying taxes. Tax morality or tax morale may be related to such determinants as fairness in a tax system and financial literacy (Alexander & Balavac-Orlic, 2022). Empirical studies show that personal moral norms and the norms of those people close to them are essential in creating taxpayers' behaviour (Bobek, Roberts, & Sweeney, 2007). Notably, several studies investigate the relationship between tax morale and the tendency to evade taxes (Alm, Martinez-Vazque, & Torgler, 2006; Alm & Torgler, 2006; Torgler, 2005). Tax morality (or tax morale) is described as intrinsic motivation to pay taxes (Torgler & Schneider, 2007) or as 'a belief in contributing to society by paying taxes' (Torgler & Schneider, 2009, p. 230). Therefore, the extent of tax evasion may be related to individuals' life satisfaction, as evidenced for Eastern European countries (Ferrer-i-Carbonell & Gërxhani, 2016). Among other factors creating tax morality, one may mention the quality of state institutions (Buehn & Schneider, 2012), the progressivity of taxes (Doerrenberg & Peichl, 2013), social capital, and political participation (Russo, 2013). Several studies confirm negative linkages between personal attitudes and tax evasion (Kaplan, Newberry, & Reckers, 1997; Kogler et al., 2013; van Dijke & Verboon, 2010). For Poland, a recent experimental study showed that high trust in authorities is sufficient to decrease the tax evasion of entrepreneurs (Batrancea et al., 2022). Based on the above, the second hypothesis was formulated.

The next group of informal employment determinants include institutional factors, such as the quality of institutions (Bayar et al., 2018) and the government's efficiency in tax evasion (Bani-Mustafa et al., 2022). The cross-country study conducted by Torgler and Schneider (2007) shows that institutional quality significantly influences the size of the shadow economy. In turn, the study by Hanousek and Palda (2004) indicates that citizens' perception of the quality of government services is an essential factor of tax evasion. Moreover, the efficiency of public money may be associated with the attitude towards paying taxes (Barone & Mocetti, 2011). Recent evidence from Bani-Mustafa et al. (2022) based on the sample of 138 countries confirms the role of government efficiency in reducing tax evasion. Based on the above considerations, the third hypothesis was formulated.

These prior empirical results allowed me to assume the following research hypotheses:

H1: There is a positive relation between the tax burden and the propensity of using informal work.

H2: There is a negative relation between tax morality among company owners/managers and the probability of using informal employment.

H3: The obstacles with setting up a business are positively associated with the higher probability of using informal employment.

RESEARCH METHODOLOGY

In the literature on informal employment and its causes, one may observe no clear consensus on the best and most reliable methods of measuring this phenomenon and the reasons for involvement in informal activities. The core issue related to the analysis of the determinants of the shadow economy and informal work is the choice of the measurement method. There are several ways to measure the extent of informal activities (Alm, 2012). In general, direct and indirect approaches may be distinguished. The most prevalent direct methods include audits of individual returns, survey research, and declaration on tax amnesty data. On the other hand, the main assumption of the indirect approach is to follow traces indicating tax evasion.

To estimate the driving forces of informal employment in Poland, the results from the survey conducted among Polish small and medium-sized enterprises (SMEs) in 2018 were used. The adequate sample comprised 952 surveys, derived from the computer-assisted telephone interview (CATI). The representativeness of this study was ensured by using quota sampling based on the specific number of companies according to the size (less than 9 employees, 10-49, and 49-250 employees). Within each group, I distinguished a stratified random sampling scheme with two strata: NUTS 2 units (Nomenclature of Territorial Units for Statistics: 16 voivodships in Poland) and four main sectors: manufacturing, construction, retail, and services (The distribution of the sample is presented in Table A1 in Appendix). Respondents included business owners or high-level managers. Given the possible limitations of a survey, I applied a set of techniques designed for surveys with sensitive questions postulated in the related literature (Gërxhani, 2007; Tourangeau & Yan, 2007), including the 'forgiving wording technique' and the gradual introduction of questions regarding informal activities. Moreover, following the approach proposed by Sauka (2008), an indirect way of asking was employed. In particular, the informal employment activity question was formulated as follows: 'Due to high non-wage labour costs, some entrepreneurs use various mechanisms to minimize these burdens. Looking at the companies operating in your industry, please assess what proportion of employees are employed informally?' As Sauka (2008) confirms, the companies' response is similar in asking about informal activities in their company and the companies in their industry. As the strengths of this approach, I can mention the minimization of the rejection rate and enhancing the level of data reliability. At the same time, several weaknesses, mainly typical for survey studies for sensitive topics, have to be acknowledged.

The dependent variable was derived from the proportion of informal employees and recoded into a binary one, where 0 means that the respondent indicates no extent of informal employees in the companies operating in their industry and 1 indicates that there is some extent of informal employees. I used this indication as a proxy for the informal employment phenomenon in a given company. I decided to use a binary outcome variable instead of a continuous one, as the precise measurement of the prevalence of informal employment based on the survey data is highly demanding. Afterwards, following the existing literature concerning determinants of informal employment, I created a set of explanatory variables. Primarily, I focused on two factors related to the tax environment: tax morality, which expresses the perceived social approval of tax avoidance in Poland, and the tax burden, representing the severity of the taxation level. Additionally, I accounted for difficulties associated with setting up a business, which may be also related to the extent of informal employment (Hudson *et al.*, 2012). Last but not least, the extent of using informal workers may vary according to size, age, location of the company, industry, and regional characteristics (Górniak, 2015). Therefore, I also added control variables which include company characteristics (size and age) and the dummies for industry and region.

In Table 1, I present the descriptive statistics of both dependent and explanatory variables used in the empirical part of this article.

Table 1. Descriptive statistics

Variables	N	mean	sd	min	max
Dependent variable					
infempl (1 for any extent of informal employment)	734	0.53	0.50	0.00	1.00
infempl_2 (the share of informal employment in total employment)	734	12.74	18.17	0	100
Explanatory variables					
tax burden (Please estimate the severity of the amount of tax burden using the following scale: 1 = no obstacle. 2 = slight obstacle. 3 = moderate obstacle. 4 = large obstacle)	952	3.19	0.86	1.00	4.00
tax morality (social approval of tax avoidance in Poland: 1 (strongly agree) to 5 (strongly disagree))	952	2.64	1.17	1.00	5.00
setting_up_business (to what extent the company's development is hampered by formalities related to setting up a business: 1 = no obstacle. 2 = slight obstacle. 3 = moderate obstacle. 4 = large obstacle)	952	1.84	0.97	1.00	4.00
micro_firm (1 if a company has less than 9 employees)	952	0.40	0.49	0.00	1.00
small_firm (1 if the company has 10-49 employees)	952	0.40	0.49	0.00	1.00
medium_firm (1 if the company has more than 50 employees)	952	0.20	0.40	0.00	1.00
young (1 if the age of the company is less than 5 years)	952	0.06	0.24	0.00	1.00
*average (*1 if the age of the company is between 5-20 years)	952	0.54	0.50	0.00	1.00
old (1 if the age of the company is more than 20 years)	952	0.40	0.49	0.00	1.00
village (1 if the company is located in a village or a city with less than 10 000 population)	952	0.26	0.44	0.00	1.00
small_city (1 if the company is located in a city with 10 000-100 000 population)	952	0.34	0.48	0.00	1.00
big_city (1 if the company is located in a city with more than 100 000 population)	952	0.40	0.49	0.00	1.00
construction (1 if the company operates in the construction sector)	952	0.11	0.31	0.00	1.00
manufacturing (1 if the company operates in the manufacturing sector)	952	0.38	0.49	0.00	1.00
retail (1 if the company operates in the retail sector)	952	0.10	0.29	0.00	1.00
service (1 if the company operates in the service sector)	952	0.42	0.49	0.00	1.00

Source: own elaboration based on the survey.

To estimate the driving forces of informal employment, the following formula was used:

$$\Pr(Y_i = 1) = F(\beta_0 + \beta_1\,Reason_i + \beta_2 Firm_i + \beta_3 Industry_j + e_i) \qquad (1)$$

in which F(z) = $e^z/(1+e^z)$ is the cumulative logistic distribution, *Reason$_i$* are variables representing possible determinants of informal employment, *Firm$_i$* is a set of variables describing companies' characteristics (enterprise size, age, and location), *Industry* accounts for the field of economic activities aggregated to construction, retail, services and manufacturing). Moreover, I controlled heterogeneity across regions using dummy variables for voivodships (16 voivodships in Poland, see Table A1 in Appendix). As my main goal is to find possible determinants impacting informal employment, I employed logistic regression modelling to assess the probability of informal employment.

RESULTS AND DISCUSSION

Table 2 presents the estimation results based on the model (1), including explanatory variables described in Table 1.

Regarding the driving forces of informal employment, my results show that the higher the tax morality of a company owner or manager, the lower the inclination towards using the informal workforce. Therefore, individual tax morality, described as indistinct motivation to pay taxes, plays an essential

role in explaining tax evasion behaviour. In this way, I confirmed the ongoing assumption on the importance of tax morality in creating tax evasion attitudes (Williams & Horodnic, 2015). As tax morality claims to be one of the non-economic factors of tax evasion (Alm & Torgler; 2006, Torgler & Schneider, 2009; Williams & Martínez, 2014), it should be not neglected in theoretical and empirical research on shadow economy. The first hypothesis (H1) was fully confirmed.

Table 2. Estimation results

Dependent variable: informal employment	(1)	(2)	(3)	(4)	(5)
tax_burden	-0.215	-0.239	-0.212	-0.185	-0.212
	[0.147]	[0.146]	[0.147]	[0.144]	[0.141]
tax morality	-0.173*	-0.174*	-0.204**	-0.155*	-0.204*
	[0.097]	[0.097]	[0.099]	[0.094]	[0.108]
setting_up_business	0.365***	0.379***	0.413***	0.408***	0.413***
	[0.126]	[0.128]	[0.132]	[0.127]	[0.124]
small_firm			-0.119	-0.169	-0.182	-0.169
			[0.188]	[0.199]	[0.192]	[0.188]
medium_firm			-0.481**	-0.515**	-0.511**	-0.515**
			[0.236]	[0.249]	[0.230]	[0.240]
young			0.255	0.321	0.343	0.321
			[0.515]	[0.534]	[0.532]	[0.569]
old	_		0.053	0.173	0.121	0.173
			[0.263]	[0.271]	[0.259]	[0.261]
village			-0.102	-0.064	-0.093	-0.064
			[0.327]	[0.336]	[0.326]	[0.352]
big_city			0.360	0.436	0.299	0.436
			[0.277]	[0.279]	[0.262]	[0.316]
construction			1.147**	1.001**	1.147**
			[0.480]	[0.458]	[0.489]
retail		_	0.073	-0.005	0.073
			[0.426]	[0.409]	[0.425]
service			0.263	0.171	0.263
			[0.303]	[0.290]	[0.303]
_cons			0.312	0.197	-0.491
			[0.785]	[0.631]	[0.614]
Regional dummies	yes	yes	yes	no	yes
N	734	734	734	734	734
Wald chi2	24.03	28.13	31.02	22.15	36.28
Prob>chi2	0.1540	0.2545	0.2702	0.0358	0.1093
Pseudo R2	0.0622	0.0691	0.0830	0.0467	0.083

Notes: Standard errors are in parentheses. Models (1-4) with robust standard errors; model (5) with robust cluster errors clustered at the district level (LAU1). Weights applied. Regional dummies are not reported. Default categories: *micro_firm, average_firm, small_city*, and *manufacturing*. *p ≤ 0.10, **p ≤ 0.05, ***p ≤ 0.01.
Source: own elaboration based on the survey.

Going further, I tested the assumption regarding the linkages between tax burden severity and the inclination to evade taxes. As past evidence indicates an inconclusive association between the level of taxes and the extent of informal activities (Nur-Tegin, 2008; Joulfaian, 2009), my results confirmed this complex relation. In particular, I could not find a statistically significant relationship between the tax burden and the inclination to use informal employment. Thus, the assumption that the tax level is not the core driving force of informal activities was justified. Therefore, the second hypothesis (H2) was rejected. The lack of straightforward association between tax burden and inclination to evade taxes may be explained by the fact that the taxpayers' decisions are impacted not only by the pure tax level, but also by the whole tax system and the general trust in government and juristic system (Abdixhiku *et al*., 2017; Bernasconi *et al*., 2017).

Besides, I tested the relation between the perceived difficulties of starting a business and an inclination to hire an informal workforce. I found that in companies where the owners or managers assess the difficulties related to setting up a business as severe, the propensity to use informal labour is greater. This may be explained by the fact that those initial obstacles may encourage entrepreneurs to hire workers on informal terms to minimize costs. Moreover, Krasniqi and Williams (2020) report that entrepreneurs who start their business informally have a higher probability of achieving growth objectives.

Analysing the control variables, I can see that informal employment is less prevalent in medium-sized enterprises, which may lead to the conclusion that mainly micro and small (below 50 employees) companies use an informal workforce. This finding aligns with the previous evidence concerning Baltic countries presented by Putniņš and Sauka (2015), showing that smaller firms tend to use an informal workforce to gain a competitive advantage over larger enterprises. It also supports the evidence for 26 transition economies provided by Abdixhiku *et al.* (2017). With reference to the age of the enterprises, I did not find any statistically significant association regarding the involvement in informal employment. Moreover, I found that companies from the construction sector show a greater propensity to employ informal workforce which is also confirmed with regard to Baltic states (Putniņš & Sauka, 2015).

My results expand and reinforce the existing research on informal employment studies. Regarding Poland, the main conclusions are in line with the research conducted by Nikulin (2020) who examines the factors impacting tax evasion proxied by underreporting of business income among Polish entrepreneurs. Similarly, the findings of Bayar *et al*. (2018) demonstrate the significance of institutional factors, such as corruption, in elucidating the extent of the shadow economy in transitional economies.

In the next step, I provided a robustness check as an extension of our baseline estimations. Instead of the binary outcome variable indicating whether the company uses informal labour or not, I employed a count variable indicating the proportion of informal workforce to total employment (*infempl_2*). I decided to use zero-inflated negative binomial regression dedicated to data where a significant part of the observations of a dependent variable equals zero. In our case, nearly 48% of answers indicated no share of informal employees. Figure 1A in the Appendix presents the distribution of the dependent variable. Moreover, using this modelling technique, I could distinguish between factors which influence the probability of informal employment (the logit part of the model: zero-inflated model) and the extent of informal employment (the count model: negative binomial model). Table 3 presents the results of the regression analysis using the zero-inflated negative binomial regression model reporting the zero-inflated part.

Firstly, by analysing the results presented in Table 3, I could check which factors impact the decision whether to use informal labour. Again, in line with our baseline estimates presented in Table 2, I confirm that the higher the tax morality, the lower the probability of using informal labour (as the coefficient for variable tax morality is positive it means a higher probability of zero, which in our model accounts for no use of informal workers). Moreover, the remaining factors, like the difficulties related to setting up a business, the size of the company, and the sector of activity indicate the same relation as in the baseline estimation.

CONCLUSIONS

The main aim of this article was to find determinants of informal employment in Poland. For this purpose, I used a company-level survey conducted among Polish enterprises. With the use of survey techniques dedicated to sensitive questions, the respondents consisting of owners or high-level managers were asked about their opinion and indication on the informal activities in Poland, and on possible obstacles in running a business.

The empirical part of this article was based on the econometric model, in which I used possible determinants of informal employment selected from the existing literature. Regarding the first hypothesis (H1), I did not find that the tax burden significantly impacts the probability of using informal employment. As the previous studies indicate no strong association in this matter (Nur-Tegin, 2008; Joulfaian, 2009), our study confirmed the lack of direct links between tax burden and tax evasion. Moreover, given the recent study for Poland conducted by Batrancea *et al*. (2022), in which the authors indicated the role of

Table 3. Econometric analysis results using a zero-inflated negative binomial regression model

Dependent variable: informal employment_2	(1)	(2)	(3)	(4)
Zero-inflated model				
tax_burden	0.138	2.041***	1.666***	0.155*
	[0.094]	[0.317]	[0.421]	[0.094]
tax morality	0.127*	1.941***	1.856***	0.117*
	[0.066]	[0.252]	[0.333]	[0.065]
setting_up_business	-0.282***	-3.005***	-2.326***	-0.269***
	[0.085]	[0.305]	[0.228]	[0.082]
small_firm	0.190	6.256***	2.234***	
	[0.180]	[1.015]	[0.605]	
medium_firm	0.501**	2.887***	2.988***	
	[0.223]	[0.689]	[0.844]	
young	0.122	10.332***	99.910***	
	[0.359]	[1.152]	[3.770]	
old	0.029	1.733***	3.536***	
	[0.168]	[0.616]	[0.639]	
village	0.179	8.150***	0.126	_
	[0.210]	[0.970]	[0.846]	
big_city	-0.140	-1.592**	-3.929***	
	[0.187]	[0.670]	[0.773]	
construction	-0.610**	-3.301***		
	[0.278]	[1.013]		
retail	-0.293	-2.274**	_	
	[0.296]	[0.945]		
service	-0.176	-5.364***		
	[0.187]	[0.745]		
_cons	-0.619***	-0.616***	-0.663***	-0.590***
	[0.078]	[0.069]	[0.066]	[0.078]
Regional dummies	yes	no	yes	yes
ll	-2058.62	-1591.41	-1582.36	-2069.88
N	734	734	734	734
N_zero	347	347	347	347

Note: Zero-inflated negative binomial regression with robust standard errors; standard errors in parentheses; regional dummies included but not reported (aside from model (2); variable description as in Table 1; default categories: micro_firm, average_firm, small_city, and manufacturing. Model 1 includes all dependent variables and regional dummies, model 2 includes all dependent variables without regional dummies, model 3 does not include sectoral variables, and model 4 includes only three variables related to main research hypotheses.

 *p ≤ 0.10, **p ≤ 0.05, ***p ≤ 0.01.
Source: own study.

trust in authorities (rather than enforcement) while creating tax evasion attitudes among Polish entrepreneurs, the low tax morality seems to be important in explaining the inclination to tax evasion. In this matter, I addressed the second hypothesis (H2) and found that the probability of using informal employment may be explained by the tax morality among company owners/managers. These results are in line with the past evidence presented in the related literature, indicating the non-economic factors like tax morality and social acceptance toward tax evasion as necessary in creating taxpayer attitudes (Williams & Horodnic, 2015). In particular, tax morality that illustrates the inner motivation to pay taxes should be considered an important determinant of tax compliance. This point of view is recently emphasized in the literature (see *e.g.,* Alm & Torgler, 2011). Moreover, the inclination to informal employment may be related to institutional factors, like those related to starting own business (H3). In this way, I confirmed the tax morality and obstacles related to setting up a business as significant factors influencing the probability of using informal labour. Moreover, I employed a set of control variables consisting of firm characteristics like age, location,

and sector type. I reported that smaller firms and those operating in the construction industry are more inclined towards using informal workers, which may be related to more substantial competitive pressure in small entities (Putniņš & Sauka, 2015).

This study contributes to the existing literature by providing new evidence of the determinants of using informal work from the perspective of enterprises. Thus far, there has been a lack of empirical studies in Poland focusing on the informal work in registered enterprises. Given the topic's relevance and the difficulties and scarcity of statistical data on informal work, this study contributes to the knowledge of the shadow economy. As I utilised primarily data collected via enterprise survey, the results are helpful in better explaining the reasons for using informal work in formally registered enterprises.

Moreover, knowing the determinants that might enhance the probability of using informal work would help create proper policy measures. In general, the measures addressed in tacking the informal work may be either 'hard' or 'soft' in nature. 'Hard' solutions are mainly based on deterrence measures like increased detection probability or penalty severity. 'Soft' solutions are directed towards increasing the awareness of benefits from tax compliance or educational programmes. Regarding Poland, proposed strategies encompass various incentives to lessen the appeal of informal employment both for employees and employers. Still, a very widely used solution is inspections conducted by The National Labour Inspectorate (PIP). In the case of detection of informal employment, PIP may impose sanctions and penalties on employers. At the same time, various forms of financing are addressed for employers, such as subsidies for creating new jobs, training for employees or development of company infrastructure. This type of financial support can help to cover some of the costs related to employment, thus encouraging formal employment.

This study reveals the importance of morality in explaining the probability of using informal work. It is not an easy task to enhance a level of tax morality among taxpayers. Following Alm and Torgler (2006), extensive educational information campaigns, tax system fairness, and trust in government may enhance tax morality. Explaining to citizens how their taxes are used can help increase their tax willingness. Showing concrete examples of tax-funded public services, such as schools, hospitals, and infrastructure can convince people that paying taxes directly impacts their quality of life. People are more likely to pay taxes when they believe the tax system is fair. This means that taxes should be proportionate to income and that all citizens, including the wealthy and corporations, should pay their fair share. A high level of trust in government and public institutions usually translates into higher tax morality. If citizens believe that the government acts in their best interests and manages public funds efficiently, they are more likely to pay taxes.

This analysis may be helpful in research on entrepreneurship, tax evasion and shadow economy stream. It indicates the heterogeneity among Polish enterprises related to the involvement in informal activities, in particular the use of informal labour. This study sheds the light onto less known dimension of 'grey activities' existing in the registered companies, which is less frequently analysed in the literature. I realize that the results contain a considerable degree of uncertainty resulting from the subjective nature of the data as well as the limitations related to the amount of data. Another limitation of this research may be related to the inferring causality: the determinants of informal employment like the tax morality may be affected by some unobservable variables, not included in our analysis. However, I believe that this evidence will help in understanding the primary motives for using informal workforce and in this way enhance further research on the nature and extent of informal employment and shadow economy in general. In particular, a larger survey sample and expansion for other countries will significantly contribute to the more profound analysis of the phenomenon of informal work in Europe. Moreover, given the global changes induced by the pandemic of Covid-19, the informal workers may be significantly impacted (Webb, McQuaid, & Rand, 2020). According to the International Labour Organization's (ILO) estimates, the increase in poverty among informal workers may be even 52 points in high-income countries and 56 points in upper-middle-income countries (ILO, 2020). A deeper investigation of the influence of the global crisis caused by coronavirus on the informal labour market may also pose interesting research areas.

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Appendix

Table A1. Overall Sample Description

Voivodship/sector	Micro firms					Small firms					Medium-sized firms				
	Manufacturing	Construction	Retail	Services	Total	Manufacturing	Construction	Retail	Services	Total	Manufacturing	Construction	Retail	Services	Total
Lower Silesian	7	4	3	19	33	12	3	4	7	26	9	1	1	4	15
Kuyavian-Pomeranian	5	0	2	10	17	10	3	3	2	18	3	1	1	4	9
Lublin	6	2	0	8	16	10	1	1	3	15	2	1	1	2	6
Lubusz	0	1	0	9	10	2	3	0	5	10	1	1	1	1	4
Łódź	10	2	1	9	22	13	3	1	8	25	7	1	1	2	11
Lesser Poland	8	1	6	18	33	17	3	5	9	34	6	2	1	6	15
Masovian	15	10	8	38	71	32	9	4	21	66	14	6	6	20	46
Opole	2	0	2	5	9	4	2	0	3	9	2	0	0	2	4
Subcarpathian	4	0	4	7	15	10	2	0	3	15	5	0	1	2	8
Podlaskie	4	2	1	2	9	1	1	1	5	8	1	1	0	2	4
Pomeranian	4	2	1	19	26	12	3	3	6	24	7	2	0	1	10
Silesian	8	7	9	18	42	22	3	4	21	50	10	1	1	12	24
Holy Cross	5	1	1	3	10	4	1	1	4	10	4	0	0	1	5
Warmian-Masurian	3	1	1	6	11	9	1	1	1	12	4	0	0	1	5
Greater Poland	7	4	3	23	37	17	5	1	18	41	13	1	1	4	19
West Pomeranian	3	2	2	13	20	6	1	2	8	17	1	1	1	3	6
Total	91	39	44	207	381	181	44	31	124	380	89	19	16	67	191

Source: own elaboration based on the survey.
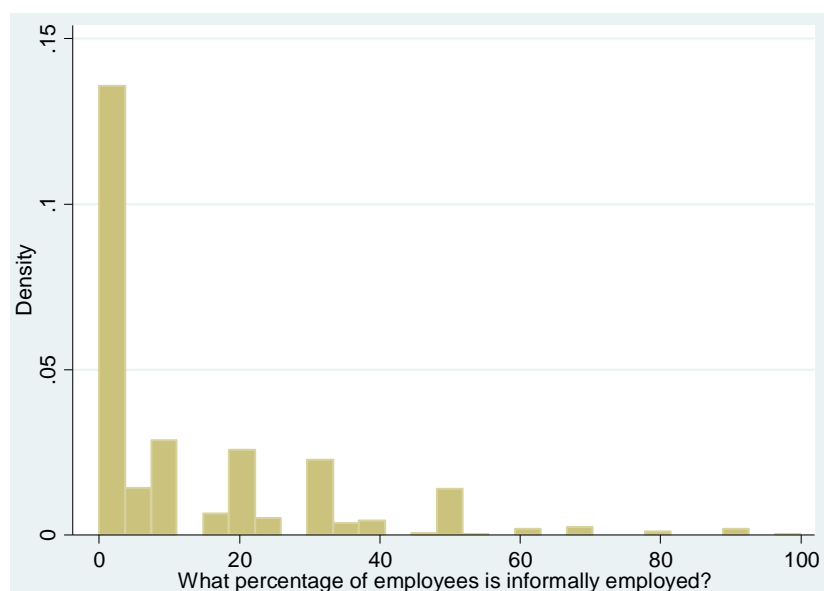
Figure A1. The distribution of the share of informal employment
Source: own elaboration based on the survey.

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Beyond the existing economic uncertainty: Spa enterprises' resilience capacity in the Polish tourism sector

Diana Dryglas, Marcin Salamaga

A B S T R A C T
Objective: The study aimed to identify and assess factors that build the resilience capacity of spa enterprises within the tourism sector in Poland in the wake of the economic crisis from managers' perspective.
Research Design & Methods: Research method characteristic for quantitative research was used. Survey data were collected from 500 tourism enterprise managers (including 80 from the spa sector) in Poland, using a self-administered questionnaire. A two-proportion Z-test was used to verify whether there were any significant differences in the percentage of selected response variants between the tourism sector and spa enterprises.
Findings: The methods used made it possible to assess financial, social, and human capital in spa enterprises as compared to the tourism sector. The results revealed that (1) the coronavirus pandemic had a more devastating impact on the financial standing of spa enterprises than on the financial situation in the tourism sector, (2) spa enterprises are more willing to use resilience actions on the regional and governmental levels than the tourism sector, and (3) spa enterprises and the tourism sector have a demand for digital competencies under their short-term and long-term recovery strategies.
Implications & Recommendations: The findings help to provide recommendations for spa and tourism enterprises for adapting their financial, social, and human policy to foster their resilience capacity and help them recover.
Contribution & Value Added: Regarding the empirical part, the results of this study contribute to the scholarly understanding of the resilience capacity of spa and tourism enterprises and the way spa and tourism enterprises assess resilience factors in response to the economic crisis. The present study will help managers of spa and tourism enterprises recognise resilience as a crisis management tool or strategy for business stability and adaptability to economically uncertain environment and new circumstances.

INTRODUCTION

The uncertain economic environment has posed critical challenges across all industries and sectors worldwide, especially the tourism sector (Kaczmarek *et al.*, 2021; Kryeziu *et al.*, 2022). Polish spa enterprises are no exception (Szromek, 2021a,b). Spa enterprises (*e.g.*, sanatoriums, spa hospitals) have been facing increasingly more difficulties related to the costs of the downturn in their business activity, including labour costs of the painstakingly acquired specialist personnel (doctors, nurses, physiotherapists, dieticians, kitchen staff) and the costs of facility maintenance. The conclusions drawn from the observation of the way Polish spa enterprises functioned after the Covid-19 pandemic justify the need to explore their resilience capacity. As one of the tourism subsectors that depend not only on the mobility of spa tourists but more importantly on public funding, spa enterprises are highly vulnerable (Sharma *et al.*, 2021; Hall

et al., 2023) to economic change and face extra pressure and instability. The concept of vulnerability is associated with the resilience concept (Miller *et al*., 2010; Soylu, 2019). The latter has rapidly been adopted in the tourism system as a way to recognize the capacity of different elements, such as industries, subsectors, destinations, communities, organisations, businesses, or individuals to respond to change (Hall *et al*., 2023). Enterprises' resilience is an important subject of study not only because of the need to improve understanding of their capacity to survive, but also because they are a core component of resilience on a sectoral level (Hall *et al*., 2023). Therefore, this article focuses on resilience at the level of spa enterprises as compared to the tourism sector. Resilient spa enterprises are a key component towards achieving a more resilient tourism sector, because spa enterprises provide essential health services for communities, including tourism staff and tourists. According to Pinos-Navarrete and Shaw (2020) and the European Spas Association (ESPA, 2020a), the coronavirus pandemic is the historical time for revival and recognition of the importance of spa enterprises and public health (Castañeda-García *et al*., 2022). The ESPA is convinced that in a post-Covid-19 world, people will be more sensitive to disease prevention and will use spa enterprises for that purpose. The spa enterprise model based on natural healing resources is available in German-speaking countries, the Baltic States (Estonia, Latvia, and Lithuania), Central and Eastern Europe, Russia and partly in France (Dryglas & Salamaga, 2018). According to the ESPA's definition, spa enterprises are facilities which carry therapeutic connotations. They are respected health centres and form a powerful economic unit generating significant proportions of the gross domestic product of the European Community Member States (ESPA, 2020a). During the Covid-19 pandemic (Bagh *et al*., 2023; Halmai, 2022), in some countries such as Serbia or Slovenia and rehabilitation centres in Germany, spa enterprises have operated as the second-line facilities included in the healthcare system to relieve hospitals (ESPA, 2020b). The 'new normal' reality necessitates the introduction of new treatment profiles in spa enterprises, *e.g*., post-Covid rehabilitation, post-Covid psychotherapy, prevention, diagnostics, redefined need for spa medicine and unification of medical procedures (Šenková *et al*., 2021). At the same time, there will be a growing need for establishing psychotherapy and psychiatric therapy centres, which is associated with the negative effects of isolation during the Covid-19 pandemic (Androniceanu & Marton, 2021). The phenomenon of resilience in tourism studies has already been examined in different frames, taking into account the ecological/environmental resilience of tourism systems (*e.g*., Loehr & Becken, 2021), organisation resilience of the tourism sector (Orchiston *et al*., 2016), the resilience of tourism enterprises to disasters (Bhaskara & Filimonau, 2021; Wieczorek-Kosmala, 2022) and resilience of tourism destinations after external shocks (Bethune *et al*., 2022). To date, the subject literature has focused on the role of spa enterprises in preventing diseases during the Covid-19 pandemic and offering a sustainable business model for spa enterprises in times of crisis (Szromek, 2021a,b). Several studies in the tourism and health tourism literature emphasise the importance of managing the crisis caused by the Covid-19 pandemic in spa and tourism enterprises (*e.g*., Kaczmarek *et al*., 2021; Plzáková & Smeral, 2022; Szromek & Polok, 2022). Furthermore, the literature on resilience in tourism includes mostly conceptual and qualitative studies (Sharma *et al*., 2021). To our knowledge, there are no studies that quantitatively evaluate the resilience of spa enterprises within the tourism sector. Therefore, the study aimed to identify and assess factors that build the resilience capacity of spa enterprises within the tourism sector in Poland in the wake of the economic crisis from managers' perspective.

As our study was exploratory rather than conclusive, its direction and structure were dictated by the aim of the study which was going to be accomplished by answering the following research questions:

RQ1: Which of the capital factors associated with resilience can help in an enterprise's response to a crisis scenario?

RQ2: What are the differences in the capital factors associated with resilience between spa enterprises and the tourism sector?

The article is structured as follows. Firstly, we will present the theoretical background of the concept of resilience in tourism and the economic situation in Polish spa enterprises during and after the pandemic. Thereafter, we will provide a description of the research methodology followed by the empirical findings. Finally, we will discuss theoretical and managerial implications and propose future research agenda.

LITERATURE REVIEW

The Concept of Resilience in Tourism

Resilience has emerged as an important concept in the tourism sector in response to the unpredictable economic environment created by the pandemic (Sharma *et al*., 2021). The economic influence of Covid-19 and other economic crises on tourism businesses have attracted more attention to the concept of resilience than ever before (Szymanik, 2020; Bhaskara & Filimonau, 2021; Gössling *et al*., 2021). The experience gained from the pandemic shows the importance of understanding the role of resilience in building and improving the capacity of the tourism system (Prayag, 2023), tourism sector (Okafor *et al*., 2022), tourism organisation (Kaczmarek *et al*., 2021), tourism destinations (Bethune *et al*., 2022), community (Jang & Kim, 2022), and tourists (Gottschalk *et al*., 2022) as a way to respond effectively and adapt positively to increasing economic change and disturbances. Therefore, tourism resilience can be perceived as a multi-level construct (Hall *et al*., 2023; Prayag, 2023), which can be adapted to the spa sector as a sub-sector of tourism (Figure 1).

Figure 1. The structure of the resilience concept in tourism
Source: own elaboration based on Hall *et al*. (2023) and Prayag (2023).

Furthermore, the resilience concept is multi-stage (proactive, adaptive, reactive, and dynamic; Supardi & Hadi, 2020). Our study treated resilience as an adaptive attribute during an event, which relates to a process rather than an outcome (Karman, 2020). Resilience as an ongoing process requires constant learning, flexibility, adaptation, and evaluation and as an outcome includes not only recovery but also transformation and/or development (Sharma *et al*., 2021). Scholars who focus on the adaptive aspect of resilience refer to resilience as the capacity of the tourism firm to remain in a stable state during a disturbance and identify 'operational agility' as a necessary component to develop resilience (Karman, 2020). The capacity to cope with turbulent changes requires capital which combines resources contributing to adaptive capacity with the ability of an organisation to recover from a crisis (Brown *et al*., 2018). The literature on tourism resilience identifies different forms of capital *e.g*., economic, social, cultural, political, and natural capital for community resilience (Stotten *et al*., 2021); psychological capital for organisational resilience (Fang *et al*., 2020), economic, social, human, physical, natural, and cultural capital for hotel sector resilience (Brown *et al*., 2018), and financial, social, and human capital for tourism enterprises resilience (Biggs *et al*., 2012). In light of the difficult economic situation in spa and tourism enterprises during the pandemic and in post-pandemic times, financial, social, and human capital are of key importance for finding a solution to the crisis. Resilience capacity measures have been undertaken to adapt their financial, social, and human policy to new requirements of the spa and tourism

market. In times of a growing demand for spa medicine services (ESPA, 2020, May 21), this will allow spa enterprises to boost their resilience and break the economic deadlock. Access to finance and a healthy financial condition is integral to enterprise survival and success (Dahles & Susilowati, 2015; Hornowski *et al.,* 2020). Financial capital is characterised by such resilience predictors as the availability of financial resources, income diversity, financial strength, and personal economic resilience of staff members (Brown *et al.*, 2018). This study used an enterprise owner's or manager's assessment of the financial condition and access to financial resources in a crisis scenario as a measure of financial capital. The acceleration of change due to ongoing economic crises confronted the tourism and spa sector with cash flow problems or revenue losses. Components which are integral to social capital are 1) social resources, connectedness, and cohesion, 2) the capacity to work as a group, and 3) trust (Brown *et al.*, 2018). In our study, social capital was associated with social networks and associations as well as government support. We believe that social capital that exists between the different levels of the government and tourism sector can provide support to enterprises in the face of crises and enable them to survive during difficult times. Recent studies have shown that both economic stimulus packages and governmental response to Covid-19, including financial instruments, help to enhance the tourism sector's recovery from the Covid-19 pandemic (Okafor *et al.*, 2022). Furthermore, non-price policies can be effective for post-pandemic recovery in the case of inexpensive tourism destinations (Esquivias *et al.*, 2021). According to Biggs *et al.* (2012), human capital is defined as the skill sets and capacity of individuals to respond and adapt to change. Brown *et al.* (2018) distinguished the following predictors of resilience within the context of human capital 1) health, 2) skills, 3) capacity to adapt, 4) knowledge, and 5) business continuity. Human capacity is in liaison with the success of an enterprise (Bosma *et al.*, 2004). Understanding this dependency leads to an increase in entrepreneurial expenses linked with employees' training and skills development. The relevant efforts are often greater at profitable enterprises (Samoliuk *et al.*, 2021). The important feature of human capital in this regard is also entrepreneur's education (Devkota *et al.*, 2022; Çera *et al.*, 2022; Ključnikov *et al.*, 2021; Roman *et al.,* 2022). In this study, human capital was associated with the capacity of the management and staff to adapt to new short-term and long-term strategic solutions. The previous findings led us to the following research question:

RQ1: Which of the capital factors associated with resilience can help in an enterprise's response to a crisis scenario?

Economic Situation in Polish Spa Enterprises During And After The Pandemic

The analysis of data from the Central Statistical Office (2022a) indicated that in 2022, 47 Polish spa resorts comprised 240 sanatoriums and spa hospitals, with nearly 45 000 beds, which constitutes 4.9% of beds in the entire tourist accommodation sector. Apart from their key health-promoting role, spa resorts are one of the fundamental drivers of the Polish tourism economy generating about 1.5-2% of the Polish GDP. The 271 spa enterprises (49 spa hospitals, 191 sanatoriums, 14 spa outpatient clinics, 17 independent natural medicine centres) in Poland employ about 17.5 thousand people, and further 80 thousand people work in the spa environment (tourism, trade, services etc.), which altogether comprises about 10% of jobs in the country. The most important achievement confirming the significant role of spa enterprises in the Polish tourism sector is the high occupancy rate of almost 80%, which is nearly two times higher than the mean for the tourist accommodation establishments in Poland (40.6%; GUS, 2022b). The spa sector comprises nearly 800 thousand spa tourists referred for inpatient and outpatient spa treatment every year.

The pandemic started in an already difficult economic situation for spa enterprises caused by the falling budget expenditure earmarked for spa medicine. In the years 2000-2022, government expenditure on spa medicine was reduced from 4.5% (1998-1999) to about 1% of the annual National Health Fund (NFZ) budget. The decreasing level of expenditure on spa medicine in the annual budget of NFZ has led to a reduction in the daily rates of stay and the number of days contracted and, in consequence, to a reduction in the number of beds in spa enterprises as well as the loss of jobs (Dryglas & Lubowiecki-Vikuk, 2019). Moreover, the absorption capacity of the EU structural funds (Androniceanu, 2020) is limited (on the one hand, state-owned spa enterprises do not have the status of a small-sized enterprise and, on the other hand, they cannot afford to provide the financial contribution that is required when applying for

EU funding), and the state will not recapitalise spa enterprises. This means that spa enterprises have to co-finance the stay of patients together with the public health insurer (NFZ) or public social insurer (Social Insurance Institution; ZUS), which leads to a reduction in their profits (Dryglas & Salamaga, 2018). Furthermore, the economic problems faced by spa enterprises have been exacerbated by the volatile situation in Ukraine. Ukrainian refugees have been received by spa enterprises in entire Poland, so the previously booked stays had to be cancelled and postponed to a later date. While the economic effects of the Covid-19 pandemic on the tourism sector have been extensively examined in the tourism literature (*e.g.*, Han *et al.*, 2022; Uglis *et al.*, 2022), there have been little studies that would attempt to assess the economic effects of the Covid-19 pandemic on spa enterprises.

Currently, spa enterprises in Poland focus on surviving and not losing the painstakingly acquired specialist personnel (doctors, nurses, physiotherapists, dieticians, kitchen staff), as many of them are facing a difficult situation of no income. It will be very difficult to recover from the loss of qualified personnel. Moreover, almost all of them are self-employed. Even doctors and nurses in sanatoriums are self-employed, not to mention the staff who service tourists. The problem is aggravating also because, in large cities, there is 'diversification' within families: even if one of the spouses is self-employed, the other works in some enterprise, a large company. And in spa resorts, entire families work as sanatorium and tourism staff.

Furthermore, spa enterprises that have contracts with NFZ are completely secure in terms of funding and can even obtain additional aid for development in the form of liquidity and preferential loans, bonds or shares, and stakes. On the other hand, the economic situation in spa enterprises that do not have contracts with NFZ is worse than in those that do have such contracts. This is because they do not have any financial support or revenues. These entities had not been included in the Regulation of the Minister of Health of 14 March 2020 (on the general terms and conditions for health care service provision contracts). These considerations led to the following research question:

RQ2: What are the differences in the capital factors associated with resilience between spa enterprises and the tourism sector?

RESEARCH METHODOLOGY

Data Collection

Because the cognitive value of the study stems from the possibility of statistical generalisation, the research goal was to be achieved based on a quantitative approach.

Data were collected using an online survey on the LimeSurvey platform between June and November 2021. One thousand surveys were addressed to the tourism sector (tourist accommodation facilities, transportation services, travel agencies, tour guides and leaders, catering services, and spa enterprises) operating in Poland. Five hundred valid questionnaires (including 80 questionnaires from spa enterprises) were obtained, yielding a response rate of 50%. Concerning the remaining 168 questionnaires, some were not filled at all and in some, the variables were found to be missing in over 50%, hence, they were excluded from the analysis. When establishing the minimal sample size, the aim was to guarantee that the margin of error does not exceed the established threshold with the confidence coefficient $1-\alpha = 0.95$. The maximum margin of error for the tourism sector was established at 4.4%. The sample size allowed for a reliable generalisation of the findings and their application to the general population.

Measurement

In this survey study, spa enterprise managers and managers of other enterprises from the tourism sector were to assess selected financial, social and human capital factors contributing to adaptive resilience during the pandemic and in post-pandemic times. Data were collected by means of a two-page self-administered questionnaire, which comprised eight questions with a set of answers to choose from. Based on the selected predictors of resilience within the context of financial capital (availability of resources and financial strength), social capital (social resources /connectedness/cohesion), and human capital (capacity to adapt, knowledge, and business continuity) (Brown *et al.*, 2018), the authors

developed a set of 55. response items to obtain information about the resilience capacity and adaptability of the spa enterprises within the tourism sector during and post the pandemic crisis. The structured questionnaire consisted of four parts. Part one covered questions related to financial capital (questions 1-3). Part two included questions on social capital (governmental financial support instruments) (questions 4-6). Part three measured human capital (questions 7-8). Finally, part four included a question on the type of tourism activity conducted.

Data Analysis

Answers to the research questions were obtained based on the results of the survey which had been carried out among respondents from the tourism sector, including those from spa enterprises. Respondents answered the questions using a nominal scale. We used a nominal scale, because it is easier for the respondent to answer a question instead of wondering what numerical level from the Likert scale to choose or what value to enter. Consequently, we managed to obtain more completed questionnaires. Furthermore, we achieved the assumed research goals by analysing the answers on a nominal scale, because they did not require the use of stronger scales. Most of them were multiple-choice questions. The percentage structure of replies given to individual questions was analysed. Thus, in the case of multiple-choice questions, the sum of relative frequency counts did not necessarily amount to 100%. A two-proportion Z-test was used to verify whether there were any significant differences in the percentage of selected response variants between the tourism sector and spa enterprises. The probability value (p-value) below 0.05 indicated a statistically significant result. The results of the test have been presented in the last two columns of the result tables, which show the structure of answers to individual questions. Calculations were performed in Statistica ver. 13.3, Minitab 17, and Excel.

RESULTS AND DISCUSSION

Financial Capital

Data presented in Table 1 show that the largest number of respondents in the tourism sector indicated that cash reserves allowed them to pay their liabilities only until 30 September 2021 (48.56% of answers), whereas in spa enterprises this was 31 December 2021 (42.86% of answers). Thus, in light of the answers obtained, spa enterprises have higher financial liquidity. However, differences in the percentage of selected response variants between the tourism sector and spa enterprises were generally not statistically significant. The two proportion Z-test results show that only in the case of response variant '2-3 years' was there a statistically significant difference between the tourism sector and spa enterprises (Z = 2.64075, p < 0.05).

Table 1. Percentage of responses to the question 'How long will you be able to rely on your cash reserves based on the economic and social information you currently have?' among representatives of the tourism sector and spa enterprises (multiple choice question)

Response item	Tourism sector	Spa enterprises	Z	p-value
Until 30 September 2021	48.56%	28.57%	1.149598	0.250310
Until 31 December 2021	35.85%	42.86%	0.415335	0.677897
30 May 2022	8.65%	14.29%	0.549286	0.582809
For 2-3 years	0.15%	14.29%	2.640750	0.008272
I have no such possibility	4.41%	0.00%	0.668577	0.503765

Source: own elaboration.

Data presented in Table 2 show that the largest number of respondents both in the tourism sector and spa enterprises indicated that their turnover would return to pre-pandemic levels within two to three years (85.84% and 100% of answers, respectively). Thus, in light of the answers obtained, the tourism sector and spa enterprises will need a similar amount of time to regain their pre-pandemic financial condition. Differences in the percentage of selected response variants between the tourism sector and spa enterprises were not statistically significant.

Table 2. Percentage of responses to the question 'When will your turnover return to pre-pandemic levels?' among representatives of the tourism sector and spa enterprises

Response item	Tourism sector	Spa enterprises	Z	p-value
By 30 September 2021	0.00%	0.00%	–	–
By 31 December 2021	0.24%	0.00%	0.155	0.877
30 May 2022	4.13%	0.00%	0.646	0.518
In 2-3 years	85.84%	100.00%	1.252	0.210
Never	7.40%	0.00%	0.878	0.380

Source: own elaboration.

Data presented in Table 3 indicate that respondents from the tourism sector were highly convinced that the recovery from the financial losses would take them several years (77.76% of answers), the demand for their services would decrease (75.85% of answers), and the situation was creating commercial conflicts within the industry (54.06% of answers). Likewise, all respondents from spa enterprises indicated that the recovery from the financial losses would take several years. Furthermore, they declared that the 500+ voucher was a good instrument and the industry demonstrated a strong sense of integration (75% of answers each). With most of the response variants, there were significant differences between the tourism sector and spa enterprises. Only in the case of three items were there no significant differences between the sectors analysed: recovery from the financial losses will take several years (Z= 1.634, p>0.05), I will permanently introduce partially remote work (Z = 1.782, p > 0.05), the industry demonstrated a strong sense of integration (Z = 1.730, p > 0.05).

Table 3. Percentage of responses to the question 'What are your predictions, plans and strategies to manage financial vulnerabilities?' among representatives of tourism sector and spa enterprises (multiple choice question)

Response item	Tourism sector	Spa enterprises	Z	p-value
Recovery from the financial losses will take several years	77.76%	100.00%	1.634	0.102
Demand for my services will decrease	75.85%	0.00%	4.517	0.000
The situation creates commercial conflicts within the industry	54.06%	0.00%	3.109	0.002
The industry demonstrated a strong sense of integration	44.79%	75.00%	1.730	0.084
It is likely that I will partially or entirely convert to some other type of business	35.75%	0.00%	2.233	0.026
I will permanently introduce partially remote work	25.55%	0.00%	1.782	0.075
The 500+ voucher is a good instrument	24.78%	75.00%	3.062	0.002
Lobbing the self-regulatory organisation has been effective	16.85%	50.00%	2.286	0.022

Source: own elaboration.

Financial capital which comprises financial standing and liquidity is similar in the tourism sector and spa enterprises. Even though the declared cash reserve depletion time was shorter in the tourism sector, the differences were not statistically significant. Compared to the tourism sector, spa enterprises have been substantially affected by the Covid-19 pandemic. The empirical research has yielded a conclusion that the decline in revenues of spa enterprises may reach an extent unprecedented since 1989, which would severely threaten the functioning of those enterprises. A similar situation has been observed in other European spa enterprises. For instance, the managing director of the Slovenian Spas Association Iztok Altbauer estimated 'an alarming 30-35% loss of revenue' (STA, 2020).

Social Capital

Data in Table 4 show that for respondents from the tourism sector, the most important sources of information about the support instruments available were personal contacts (69.5% of answers), social media/forums/groups (60.17% of answers), and official government announcements at www.gov.pl (47.73% of answers). In turn, information sources selected equally often by spa enterprises were the Ministry of Economic Development, official government announcements at www.gov.pl, voivodship office, marshal's office, voivodship/poviat labour office, social media/forums/groups, and personal

contacts (100% of answers each). With most of the response variants, there were significant differences between the tourism sector and spa enterprises (in these cases a higher percentage of answers was observed for spa enterprises). Only in the case of three items were there no significant differences between the sectors analysed. These were city/municipality office (Z= 1.912, p>0.05), self-regulatory organisation/chambers/associations (Z= 0.970, p>0.05), media, TV, and Radio (Z= 1.164, p>0.05).

Table 4. Percentage of responses to the question 'What sources of information about the support instruments available did you find most useful?' among representatives of the tourism sector and spa enterprises (multiple choice question)

Response item	Tourism sector	Spa enterprises	Z	p-value
Personal contacts	69.50%	100.00%	2.000	0.045
Social media/forums/groups	60.17%	100.00%	2.417	0.016
Official government announcements at www.gov.pl	47.73%	100.00%	3.016	0.003
Voivodship/poviat labour office	45.36%	100.00%	3.139	0.002
Marshal's office	34.09%	100.00%	3.796	0.000
Self-regulatory organisations/chambers/associations	33.71%	50.00%	0.970	0.332
Webinars	31.75%	0.00%	2.056	0.040
Media, TV, radio	30.77%	50.00%	1.164	0.245
City/municipality office	20.87%	50.00%	1.912	0.056
Ministry of Economic Development	20.01%	100.00%	4.878	0.000
Voivodship office	17.41%	100.00%	5.130	0.000
Information from the municipality office	13.22%	50.00%	2.679	0.007

Source: own elaboration.

Data in Table 5 show that respondents from the tourism sector would mostly expect the following types of support: support for the promotion of tourism abroad and domestic tourism in the regions (83.89% of answers) followed by extensive access to information about the possible financing earmarked for tourism enterprises from the national and EU funds (82.28% of answers). As for spa enterprises, the most important type of expected support was systemic domestic demand financing, *e.g.*, through personal income tax (PIT) relief (PLN 1000 per person on income for five years) (100% of answers) followed by access to information about the possibility of receiving financing earmarked for tourism enterprises from the national and EU funds (83.33% of answers). A statistically significant difference between the tourism sector and spa enterprises was observed only in the case of one item: systemic domestic demand financing, *e.g.*, through PIT relief (PLN 1000 per person on income for five years) (Z = 2.419, p < 0.05).

Table 5. Percentage of responses to the question 'What kind of support would you expect for the domestic tourism market?' among representatives of the tourism sector and spa enterprises (multiple choice question)

Response item	Tourism sector	Spa enterprises	Z	p-value
Support for the promotion of tourism abroad and domestic tourism in the regions	83.89%	66.67%	1.260	0.208
Extensive information about the possibility of receiving financing earmarked for tourism enterprises from the national and EU funds	82.28%	83.33%	0.080	0.937
Systemic domestic demand financing, *e.g.*, through PIT relief (PLN 1000 per person on income for five years)	60.13%	100.00%	2.419	0.016

Source: own elaboration.

Data in Table 6 show that respondents from the tourism sector expected changes mainly in the strategic approach of the state and local authorities to the fields of the economy associated with tourism (understanding the essence of tourism) (85.43% of answers) followed by changes in tourism education changed/adjusted to the needs of companies and the new tourism market. As for respondents from spa enterprises, the most expected changes also pertained to the strategic ap-

proach of the state and local authorities to the fields of the economy associated with tourism (understanding the essence of tourism) (66.67% of answers), as well as extensive information about the international tourism market, including that about Covid-19 restrictions (50.00% of answers). A statistically significant difference between the tourism sector and spa enterprises was observed only in the case of one item: extensive information about the international tourism market, including that about Covid-19 restrictions ($Z = 2.182$, $p < 0.05$).

Table 6. Percentage of responses to the question 'What should be changed within social resources ?' among representatives of the tourism sector and spa enterprises (multiple choice question)

Response item	Tourism sector	Spa enterprises	Z	p-value
Strategic approach of the state and local authorities to the fields of economy supporting tourism (understanding the essence of tourism)	85.43%	66.67%	1.412	0.158
Tourism education changed/adjusted to the needs of companies and the new tourism market	61.90%	33.33%	1.654	0.098
Extended financing for the use of IT (digitisation, automation) in tourism sectors	53.94%	33.33%	1.180	0.238
Marketing communication channels in tourism	43.54%	33.33%	0.593	0.554
Extensive information about the international tourism market, including that about Covid-19 restrictions	34.60%	0.00%	2.182	0.029
Extensive information about the domestic tourism market, including that about Covid-19 restrictions	31.99%	50.00%	1.082	0.279

Source: own elaboration.

As per social capital, the tourism sector and spa enterprises have generally differed in terms of the support instruments used and the level of importance assigned to them. This may stem from the different nature and activity profile, and the legal form applying to entities within the broadly understood tourism sector as compared to spa enterprises. For the tourism sector, the most important sources of information about the support instruments are personal contacts and social media/forums/groups, whereas spa enterprises perceive value added in information published on governmental websites at the national and regional levels. Okafor *et al.* (2022) stressed that personal, regional and governmental levels of resilience actions are important.

Human Capital

Data in Table 7 show that respondents from the tourism sector in order to adapt to new circumstances focused mainly on developing e-commerce channels (67.84% of answers), using flexible forms of work (61.66% of answers), and lowering the pre-Covid-19 price (54.97% of answers). In turn, answers selected equally often by respondents from spa enterprises were: the use of flexible forms of work, greater flexibility in organising work (*e.g.*, remote work, shifts), introduction of crisis management procedures, digitisation of in-house services, digitisation of outsourced services, development of e-commerce channels, renegotiation of the current supply contracts and lowering of the pre-Covid-19 price (66.67% of answers). With most of the response variants, there were no significant differences between the tourism sector and spa enterprises, except for the digitisation of in-house services ($Z= 2.487$, $p<0.05$) and the renegotiation of the current supply contracts ($Z= 2.285$, $p<0.05$). In these two cases, the differences were significant (the percentage of respondents from spa enterprises who selected these answers was significantly higher compared to the percentage of respondents from the tourism sector).

Data in Table 8 show that the action within human capital planned for the next few years both in the tourism sector and spa enterprises is the development of new applications to reach the customer (64.08% and 50.00% of answers, respectively). This was followed by the development of new strategies for company growth, including investment contribution (for innovations) (60.74% of answers) and the development of new information, web, and sales platforms (49.88% of answers) in the tourism sector. As for spa enterprises, their long-term planning also included the development of new information,

web, and sales platforms (50.00% of answers). There were no significant differences between the tourism sector and spa enterprises for any of the response variants.

Table 7. Percentage of responses to the question 'What changes may the current situation cause in business continuity, what new procedures and solutions are you implementing or planning to implement for its adaptation to new circumstances?' among representatives of tourism sector and spa enterprises (multiple choice question)

Response item	Tourism sector	Spa enterprises	Z	p-value
Development of e-commerce channels	67.84%	66.67%	0.072	0.943
Use of flexible forms of work	61.66%	66.67%	0.296	0.767
Lowering the pre-Covid-19 price	54.97%	66.67%	0.676	0.499
Greater flexibility in organising work (*e.g.*, remote work, shifts)	52.11%	66.67%	0.837	0.403
Introduction of crisis management procedures	49.04%	66.67%	1.010	0.312
Digitisation of outsourced services	40.75%	66.67%	1.492	0.136
Diversification of supply sources	34.07%	33.33%	0.044	0.965
Renegotiation of the current supply contracts	28.66%	66.67%	2.285	0.022
Digitisation of in-house services	25.99%	66.67%	2.487	0.013
Outsourcing of in-house processes	12.14%	33.33%	1.676	0.094
Capital, network merger	10.13%	0.00%	1.040	0.299

Source: own elaboration.

The results related to human capital indicate that despite the differing specifics of their business, managers from the tourism sector and spa enterprises have a demand for similar adaptation skills under short-term and long-term recovery strategies. They believe that a special focus needs to be placed on digital competencies, which will allow them to recover from the crisis caused by the pandemic, *e.g.*, the development of new applications and online platforms to reach the customer. According to Dryglas and Klimkiewicz (2022) spa enterprises will face the challenge of adjusting to the IT requirements in terms of creating central data and fast information transfer (digitisation and development of new technologies, automation and robotisation, and replacement of some services provided by people with dedicated technologies). Spa enterprises would like to focus primarily on introducing changes in the ways of new knowledge acquisition (*e.g.*, IT, medical knowledge in the field of rehabilitation and prevention, specialist knowledge in the field of healthy eating, advancements in treatment methods, and knowledge about *e.g.*, phytotherapy, alternative treatment methods) (Buxton & Michopoulou, 2021). To support their staff, spa enterprise managers will focus on improving their skills in taking care of patients suffering from mental illnesses, handling new IT solutions, and creating friendly conditions for patients with lifestyle diseases or those who underwent Covid treatment. Other important aspects include the support in using new technologies, the development of e-marketing competencies, and access to knowledge (a platform presenting reliable data from other countries regarding restrictions and new opportunities). Spa enterprises believe that a special focus should be

Table 8. Percentage of responses to the question 'What skills and knowledge should be the main focus in your firm for the next few years?' among representatives of tourism sector and spa enterprises (multiple choice question)

Response item	Tourism sector	Spa enterprises	Z	p-value
Development of new applications to reach the customer	64.08%	50.00%	0.830	0.407
Development of new strategies for company growth, including investment contribution (for innovations)	60.74%	33.33%	1.582	0.114
Use of the Blockchain platform	6.34%	0.00%	0.808	0.419
Development of new information, web, and sales platforms	49.88%	50.00%	0.007	0.994
Development of national, international company networks	21.67%	0.00%	1.608	0.108
Use of the 5G technology	13.06%	0.00%	1.197	0.231

Source: own elaboration.

placed on the social competencies of staff working in the spa sector (*e.g.*, stress resistance, interpersonal communication, ability to make a fast diagnosis of the socioeconomic situation, ability to devote time to other people, listening to their problems; Smith *et al.*, 2021).

CONCLUSIONS

This study demonstrated that factors building the resilience capacity in spa enterprises and the tourism sector at a time of existing economic uncertainty can be divided into financial capital, social capital, and human capital. The response options and the ability of vulnerable spa enterprises and the tourism sector to cope with the shocks and changes associated with economic change revealed some differences and similarities between them. Furthermore, it turned out that resilient spa enterprises play an increasingly important role in the process of strengthening the tourism sector.

Regarding the empirical part, the results of this study contribute to the scholarly understanding of the resilience capacity of spa and tourism enterprises, and the way spa and tourism enterprises assess resilience factors in response to the economic crisis. The present study will help managers of spa and tourism enterprises recognise resilience as a tool or strategy for business stability and adaptability to economically uncertain environment and new circumstances. The study provides actionable insights to help spa and tourism enterprises recover economically and help them build lasting capabilities through the improvement of their financial standing, governmental support, and the development of digital competencies. The economic crisis can be seen as an opportunity for managers to rethink the old strategies and implement improvements, which will foster the resilience capacity of spa and tourism enterprises and help them not only recover but also transform into a much more sustainable form.

Limitations and Further Research Directions

The research framework could be supplemented with, firstly, an assessment of the resilience capacity of spa enterprises and the tourism sector from the perspective of employees and customers, which would allow for identifying correlations between the reactions of the entities mentioned and the already researched entities. Secondly, the research framework should include the identification and assessment of resilience factors other than the financial, social, and human ones, such as physical, natural, cultural, and psychological, which would allow for a holistic approach to crisis management strategies for spa enterprises and the tourism sector. Thirdly, it seems that research allowing for a comparative analysis of the perception of the resilience capacity of spa enterprises and the tourism sector both in time (taking into account the process of economic crisis spread) and space (considering other spa enterprises located in the territory of German-speaking countries, in parts of France, the Baltic States – Estonia, Latvia and Lithuania, Central and Eastern Europe, and Russia) could help create universal solutions for spa enterprise crisis management in Europe. Finally, since there is a potential for creating new theories based on spa enterprise crisis management, the research strategy employed should be based on longitudinal research.

In the face of the devastating effects of the coronavirus pandemic on spa enterprises in Europe on the one hand and insufficient research on the resilience capacity of spa enterprises on the other hand, the case study presented is the missing link in the cognitively valuable direction of investigations. The research on the resilience capacity of spa enterprises in Poland could be used by other scientists researching the field of spa enterprise management, thus increasing the chances for conducting more replication and comparative research in the future. Further research that would build upon and clarify the resilience factors of spa enterprises in response to the coronavirus pandemic would be valuable for both academics and practitioners.

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Conflict of Interest

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Forging innovation cooperation in Central and Eastern Europe: Unveiling the location role in biopharmaceutical industry

Łukasz Puślecki

A B S T R A C T
Objective: The article aims to verify the development of innovation cooperation in the biopharmaceutical (biotech, pharma) industry in Central and Eastern Europe (CEE) taking into account the directions of innovation cooperation. I will try to verify the importance of location in innovation cooperation in the biopharmaceutical industry in the CEE region, mainly if the frequency of cooperation within research and development (R&D) alliances with CEE partners is higher than with non-CEE partners.
Research Design & Methods: This is one of the first quantitative primary research articles in the world focused on innovation cooperation in the biopharmaceutical industry in the CEE region (covering 18 CEE countries), in the years 2015-2017. I conducted an online survey and collected data from January 2019 to March 2020 (a long-lasting process). The sampling procedure was non-random (purposeful selection with snowballing technique). To verify the directions of cooperation within R&D alliances in the biopharmaceutical industry, I investigated 241 R&D alliances conducted by 107 companies from the CEE region in the years 2015-2017.
Findings: The results show that the frequency of cooperation within R&D alliances with CEE partners was higher than with non-CEE partners (for selected partners and sectors). Moreover, according to the analysis of 241 R&D alliances, I observed the same results, i.e. companies from the CEE region – taking into account the direction of innovation cooperation – are more willing to develop R&D alliances with partners from the CEE region (including partners from the domestic market) than with partners outside the CEE region (North America, Western Europe, Asia) in the biopharmaceutical industry.
Implications & Recommendations: In the difficult times of the Covid-19 pandemic, companies should be more open to cooperation and use local potential and local partners to develop better therapies for patients. With more flexible modes of cooperation, it is possible to deliver new solutions and better patient treatment to the market faster, which is particularly germane to responses to the current Covid-19 pandemic, and potential future pandemics.
Contribution & Value Added: The involvement of all partners, both from the local and regional level, from business and academia, in the innovation cooperation positively impacts the innovation cooperation performance. The identified directions of innovation cooperation in CEE countries may contribute to the development of innovation cooperation in the CEE countries in the future and greater exploitation of the innovation and educational potential of the biopharmaceutical industry in the domestic market and the entire CEE region (clinical trials, clusters, science and technology parks, academia, institutions).
Article type: research article
Keywords: R&D alliances; innovation cooperation; biopharmaceutical industry; business-academia cooperation; location; Central and Eastern Europe; CEE
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INTRODUCTION

Considering the past 30 years, R&D cooperation is a fundamental component of innovation strategies. The economic and management literature offers numerous insightful publications on R&D cooperation among companies considering various forms of collaboration, such as technology transfer, technology exchange, R&D arrangements, and joint ventures (Casson, 1987; Contractor & Lorange, 1988; Piwowar-Sulej & Podsiadły, 2022; Miłoś, 2021). We can categorize technological agreements based on the nature of relationships between companies, ranging from one-directional arrangements to those with stronger organizational ties, like joint ventures and research corporations. On the other end of the spectrum, there are agreements with fewer organizational dependencies, such as contractual arrangements like technology exchange agreements or joint R&D agreements. These differing forms of technological cooperation can have varying effects on technology sharing, competitiveness levels, organizational dynamics, and potential economic outcomes for the participating companies (Contractor & Lorange, 1988; Hagedoorn, 1990; Hagedoorn, Link & Vonortas, 2000; Gomes-Casseres, Hagedoorn & Jaffe, 2006; Puślecki, 2010; Wybieralski, 2015).

Technological cooperation serves as a crucial channel for knowledge diffusion in both the public and private sectors (Androniceanu et al., 2022). Companies have been increasingly utilizing global strategic partnerships to bolster their competitive positions. Moreover, R&D alliances enable partners to improve core competencies and skills, acquire new technologies, share the risks involved in developing new technologies, and access emerging markets (Puślecki, 2010; Wybieralski, 2015; Androniceanu, 2023). Consequently, such collaborations lead to improved innovation cooperation performance (Jaklič *et al.*, 2014; Trąpczyński, Puślecki & Staszków, 2018; Tvaronaviciene & Burinskas, 2021).

The article aims mainly to verify the development of innovation cooperation in the biopharmaceutical (biotech, pharma) industry in Central and Eastern Europe (CEE) taking into account the directions of innovation cooperation. I will verify the importance of location in innovation cooperation in the biopharmaceutical industry in the CEE region, mainly if the frequency of cooperation within R&D alliances with CEE partners is higher than with non-CEE partners. This is one of the first quantitative primary research articles in the world focused on innovation cooperation in the biopharmaceutical industry in the CEE region (covering 18 countries), in the years 2015-2017. To verify the directions of cooperation within R&D alliances in the biopharmaceutical industry, I investigated 241 R&D alliances conducted by 107 companies from the CEE region between 2015-2017.

Biopharmaceutical companies (operating in the biotech and pharma industry) try to implement various forms of cooperation within the industry with universities or research institutes, institutions, and more often cross-industry alliances that may help share the costs of R&D investment and minimize the risk (Gomes-Casseres, 2014; Puślecki, 2015, 2016). This cooperation is very important in combating Covid-19 pandemic quicker, preparing for the potential future pandemics (Bourla, 2022; Gorynia, 2023; Puślecki, 2021; Puślecki *et al.*, 2022), and building innovation resilience to rapid changes in the environment as a condition for continuity of innovation (Jaklič, Puślecki & Trąpczyński, 2023; Nowiński, Rymarczyk & Starzyk, 2022; Puślecki *et al.*, 2022; Gorynia, 2023).

The article draws on issues addressed in innovation theory (Schumpeter, 1934, 1939, 1942) and it is embedded in the biopharmaceutical industry, thus constituting a kind of meso-economic study (Gorynia, 1995). I studied one of the economic mesosystems, the biopharmaceutical industry, *i.e.* the mid-level system, narrowing the focus to innovation cooperation. The thread of cooperation central to this study is also widely discussed within the framework of economic systems regulation theory (Weresa, 2022). Moreover, although, the article focuses mainly on the innovation thread, the study made it possible to determine how a given way of regulating the behaviour of firms through R&D alliances can contribute to the innovation of these partners, which ultimately translates into the competitiveness of the economy. It is also important to take a broader view of innovation cooperation and firm performance not just in one country but in the CEE region (Jaklič *et al.*, 2014; Wach, 2020; Barłożewski & Trąpczyński, 2021; Gorynia & Trąpczyński, 2017, 2022).

The post-transition countries of CEE have seen a significant increase in foreign direct investment (Trąpczyński *et al*., 2016; Gorynia *et al*., 2019, 2022), the location of new companies, and new service centres (BPO/ITO/SSC) for foreign entities, particularly in the last 15 years. The CEE region is an emerging and dynamic market that offers many business opportunities. Central and Eastern Europe offers significant growth opportunities and more competitive business costs than established EU markets. This makes the region an attractive location for international companies to trade and invest, often through strategic alliances, including R&D alliances. Noteworthy, the CEE region is less represented when it comes to research in the field of, for example, international business than *e.g.* Western Europe (Schuh, 2012, 2021; Schuh & Rossmann, 2009; Puślecki & Trąpczyński, 2014; Puślecki, Trąpczyński & Staszków, 2016; Trąpczyński, Puślecki & Jarosiński, 2016; Jaklič *et al*., 2020; Schuh, Trąpczyński & Puślecki, 2024; Jaklič, Puślecki & Trąpczyński, 2023).

The article is structured as follows. Firstly, I will present the literature review regarding the R&D alliances and the role of location in the development of innovation cooperation and use it to formulate hypotheses on the example of the biopharmaceutical industry. Subsequently, I will present the methodology of my empirical data collection, the findings both for innovation cooperation in the CEE region in the biopharmaceutical industry, and the direction of cooperation, taking into account the role of location. In the final part of the article, I will discuss the findings, limitations, and implications and indicate future research potential.

LITERATURE REVIEW AND HYPOTHESES DEVELOPMENT

We may describe strategic alliances as a specialized form of collaboration between at least two parties, which may be competitors or partners operating in the same or related sectors. Above all, these alliances aim to achieve common goals by utilizing available resources while maintaining the autonomy of each partner. These alliances cover various fields and areas not explicitly covered by the partnership agreement (Gomes-Casseres, 1996; Gulati & Singh, 1998; Das, 2005; Duyster & Hagedoorn, 2000; Puślecki, 2010; Wybieralski, 2015).

The partners involved in strategic alliances typically comprise two firms, but they can also involve research institutes, universities, government institutions, or non-profit organizations (Baum *et al*., 2000; Puślecki & Staszków, 2015; Puślecki, 2015, 2016). Partners implement strategic technology alliances primarily through joint ventures, equity alliances (where two or more partners form a separate entity), or non-equity alliances within R&D cooperation agreements (Bartolacci *et al*., 2022). The R&D alliances are characterized as innovation-based partnerships formed by multiple participants who pool their resources and coordinate their activities to achieve a common objective and where R&D activities play a significant role (Hagedoorn, 2002). These alliances appear in the literature under various terms, such as strategic technology partnering, strategic technology alliances, technological cooperative agreements, technological alliances, innovation cooperation, or cooperative R&D (Duysters & Hagedoorn, 2000; Puślecki, 2010; Wybieralski, 2015; Narula & Martínez-Noya, 2015; Martínez-Noya & Narula, 2018). We can consider technological alliances as strategic when they enhance the long-term market perspectives of at least one company involved in the cooperation. Furthermore, technological partnerships entail cooperation that involves some degree of innovative activity or the exchange of technology between partners (Hagedoorn, 1990, 1993, 2002; Duysters & Hagedoorn, 2000). The diverse definitions of R&D alliances across the economic, international business, and management literature reflect the multidisciplinary nature of the subject (Narula & Martínez-Noya, 2015; Martínez-Noya & Narula, 2018).

The R&D alliances offer various advantages to partners engaged in innovation cooperation. These advantages include access to complementary resources necessary for improving products or processes or developing new ones, the opportunity to explore new markets, cost reduction, risk mitigation, increased flexibility in partner selection, and faster time-to-market (Narula & Duning, 1998; Duysters & Hagedoorn, 2000; Hagedoorn, Link & Vonortas, 2000; Sakakibara, 2002; Nowak, 2021; Tomášková & Kaňovská, 2022). Analysing the growth and development of R&D alliances (Puślecki, 2010, 2012; Wybieralski, 2015), existing literature explains their formation through two main perspectives (Narula

& Dunning, 1998; Martínez-Noya & Narula, 2018). The first perspective is transaction cost theory, which considers the economization aspect (Williamson, 1975; Hennart, 1988; Pisano & Teece, 1989). The second perspective takes a strategic approach and involves various other theoretical frameworks, such as the resource-based theory of the firm (Barney, 1991; Das & Teng, 2000; Wernerfelt, 1984), organizational learning and knowledge-based view (Kogut & Zander, 1993), social network theory (Gulati, 1995; Powell & Grodal, 2005), and the dynamic capabilities approach (Teece, Pisano & Shuen, 1997; Zollo & Winter, 2002).

Recent literature regarding R&D alliances (Martínez-Noya & Narula, 2018) highlights that alliances are not solely motivated by cost minimization but are also influenced by value-enhancing factors, such as market growth and inter-firm learning through alliances. Firms establish R&D alliances to strengthen their organizational and technological capabilities (Das & Teng, 2000) and create value by leveraging existing assets, developing new or improved products and innovation capabilities, acquiring complementary resources, and entering new markets (Gulati, 1998; Sakakibara, 2002; Martínez-Noya & Narula, 2018). These strategic considerations are particularly important in emerging technological sectors like the biopharmaceutical industry.

The diversity of fields of cooperation (new, developed, and advanced technologies), the dynamic and turbulent environment (*e.g.* exacerbated by the COVID-19 pandemic), high uncertainty and the complexity of alliance management require from companies a both broader range of skills and competencies and resources and partners from different locations and levels (Hagedoorn, 1993; Granstrand, Patel & Pavitt, 1997; Gulati, 1998; Leiblein & Miller, 2003; Mol, 2005; Nicholls-Nixon & Woo, 2003; Świadek et al., 2022; Puślecki, 2010, 2021; Puślecki *et al.*, 2022; Quinn, 2000; Martínez-Noya & Narula, 2018; Wybieralski, 2015). This situation has prompted companies to adopt a portfolio of R&D alliances for accessing complementary capabilities and resources from different partners and locations (Hamel, 1991; Hong & Snell, 2013; 2014; Howard *et al.*, 2016).

Currently, scholars consider both transactions cost minimization and value-enhancing motives as complementary to each other in forming R&D alliances. Many studies in the literature combine both approaches. Very few alliances are distinctly driven by one motivation over the other (Lai & Chang, 2010; Martínez-Noya & Narula, 2018).

Considering the establishment of R&D alliances, certain scenarios may arise, in which the decision on the location happens made beforehand. For instance, some firms may seek to form alliances with partners in specific locations to gain location-specific advantages through their alliance partner (Henisz, 2000; Santangelo, Meyer & Jindra, 2016; Trąpczyński, Puślecki & Staszków, 2018). Once the desired location is determined, the company then selects the appropriate partner from the available alternatives in that location. On the other hand, in some cases, the focus is on choosing the type of partner based on their technological capabilities, regardless of the location (Martínez-Noya & Narula, 2018).

Previous literature indicates a preference for geographically close partners in addition to a preference for known partners (Narula & Martínez-Noya, 2015). Due to information asymmetry, firms forging R&D alliances encounter high information costs, leading to significant search and evaluation costs for potential alliance partners and exposing them to the risk of adverse selection (Reuer & Lahiri, 2014). Opting for a spatially close partner offers the advantage of better control, which is crucial in R&D alliances to mitigate the risk of knowledge loss (Li *et al.*, 2008). Because of that, R&D alliance formation tends to decrease with increasing geographical distance (Reuer & Lahiri, 2014). According to Capaldo and Petruzzelli (2014) who conducted a study on knowledge-creating R&D alliances, the geographical distance between the allied firms and their membership in the same business group negatively impacts alliances' innovation performance. However, their study highlighted that the presence of direct and indirect prior linkages between the exchange partners mitigates the negative effect of geographical distance on R&D alliance formation. Direct prior linkages result from past collaborations, while indirect linkages are established through common partners. These prior linkages help reduce information asymmetry and the risk of adverse selection, as they provide better information about a potential partner's actual capabilities and resources (Zaheer, Hernanderz & Banerjee, 2010; Martínez-Noya & Narula, 2018).

Another area of research examines whether R&D alliances can act as substitutes or complements for co-location in specific regions. Results of previous studies show that firms may co-locate with

other companies to internalize location-specific advantages and boost firm innovation or avoid co-location to reduce the risk of unintentional knowledge leakage (Alcácer, 2006; Narula & Santangelo, 2009, 2012). Because R&D is a knowledge-based activity, it is often tied to location (Cantwell & Santangelo, 1999), certain locations can offer expertise or capabilities in specific technological fields. Establishing R&D activities in foreign locations can be costly and time-consuming, making alliances with partners in those economies a more attractive option for accessing external resources and technological expertise (Cantwell & Santangelo, 1999; Puślecki, 2010; Wybieralski, 2015; Trąpczyński, Puślecki & Staszków, 2018; Martínez-Noya & Narula, 2018).

Through international R&D alliances, firms can exploit country-specific advantages possessed by their cooperating partners, making them a tool for leveraging the comparative advantages of foreign countries (Gomes-Cessares, Hagedoorn & Jaffe, 2006). Furthermore, it will be interesting to explore how firms from emerging countries may differ in their R&D decisions and alliance choices in comparison to firms from developed countries, considering factors like risk perception shaped by the country of origin (Narula & Sadowski, 2002; García-Canal & Guillén, 2008; Awate *et al.*, 2015). Moreover, analysing how firms from developed countries engage in innovation cooperation with firms from emerging countries, including CEE countries, presents an interesting avenue for investigation (Trąpczyński, Puślecki & Staszków, 2018; Martínez-Noya & Narula, 2018; Puślecki, Trąpczyński & Staszków, 2016; Puślecki & Trąpczyński, 2014; Schuh, Trąpczyński & Puślecki, 2024; Jaklič *et al.,* 2014, 2020; Jaklič, Puślecki & Trąpczyński, 2023).

The development of innovation collaboration with different partners has become a common phenomenon in contemporary business (Jaklič *et al.,* 2014; Puślecki, 2015, 2016, 2021; Szczepańska-Woszczyna & Gatnar, 2022: Samoilikova *et al.*, 2023). Trąpczyński, Puślecki, and Staszków (2018) conducted a review of the existing literature on international business, alliances, inter-firm collaboration, innovation, open innovation, which allowed them to develop the determinants of innovation cooperation performance based on a conceptual framework with three levels of analysis: (a) dyadic level, (b) network level, and (c) location level. They identified roadmaps in each of these areas and presented existing gaps in the current understanding of innovation cooperation. They argue that in addition to the dyadic level of collaboration (collaboration between two organisations), not only the network level of analysis, but also the location in which the cooperation takes place should also be taken into consideration to have a full understanding of the performance of innovation cooperation. It is important to include location effects to better understand the driving forces behind innovation cooperation and its outcomes. Their presented conceptual framework does not distinguish between innovations generated by actors nested at these different levels (from micro to macro). Trąpczyński, Puślecki, and Staszków call for an integration of the determinants of innovation outcomes, which are rooted not only in the characteristics of the firm or its partner, or in their collaborative design, as presented in most studies, but also in the innovation network as a whole and in the place where the cooperation takes place (Trąpczyński, Puślecki & Staszków, 2018).

Considering the abovementioned aspects, I developed three hypotheses:

H1: The frequency of cooperation in the biopharmaceutical industry in the CEE region within R&D alliances with CEE partners is higher than with non-CEE partners.

H2: The increase in the frequency of collaboration within R&D alliances in the biopharmaceutical industry in the CEE region is significantly associated with an increase in a firm's R&D alliance success rate.

H3: The companies from the CEE region in the biopharmaceutical industry are more willing to develop R&D alliances with partners from the CEE region rather than with partners outside the CEE region (non-CEE) taking into account the direction of innovation cooperation.

RESEARCH METHODOLOGY

In this research, I used the quantitative method. I conducted an online survey (including an online questionnaire) regarding innovation cooperation in the biopharmaceutical industry in the CEE region

in the years 2015-2017. I collected data from January 2019 to March 2020 (a long process of 15 months) from 20 CEE countries. The sampling procedure was non-random (purposeful selection with snowballing technique). I used LinkedIn platform to distribute the questionnaire (contact with over 400 managers from the CEE region), data obtained from the database AMADEUS (Bureau van Dijk Electronic Publishing), industry portals, *e.g.* Pharmaboardroom, direct email and telephone contact with companies. Moreover, I used pharma and biotech associations to request the distribution of the questionnaire. *i.e.* within EFPIA (European Federation of Pharmaceutical Industries and Associations) Belgium and EFPIA representatives in the CEE countries, INFARMA (The Employers' Union of Innovative Pharmaceutical Companies, Poland), Farmacja Polska (Poland), and organisations preparing industry events like CEBIOFORUM and CEHE (Central European Healthcare Expo), in which I received support from the partners from the academia in the CEE region within the Academy of International Business – Central and Eastern Europe Chapter (AIB-CEE) for distribution of the questionnaire in CEE countries. Thanks to all these efforts, I could distribute the questionnaire to approximately 2000 companies and stakeholders in the biopharmaceutical industry in 20 CEE countries (biotechnology, pharmaceutical, biopharmaceutical companies, national and international industry associations). The return rate of the questionnaires used for the analysis was *ca.* 5%, which amounts to 187 (return rate of 9.5%) and of which 107 companies from 18 CEE countries (approx. 5% of the surveyed population) responded to all the questions required in the questionnaire. Due to the small sample size (n=107), I could not generalise the results obtained from the quantitative studies conducted for the whole population. Noteworthy, it is one of the first quantitative primary research articles in the world focused on innovation cooperation in the biopharmaceutical industry in the CEE region in the years 2015-2017 (covering 18 CEE countries). Therefore, we may treat the study results as exploratory. Moreover, the results are based on unique primary data (which is not so usual in the innovation cooperation analysis in the previous studies as a lot of studies were based on secondary data and used for instance Community Innovation Survey (CIS)).

To verify hypotheses **H1** and **H2,** I analysed the innovation cooperation in the biopharmaceutical industry of 107 companies in the years 2015-2017 in the CEE region. To verify hypothesis **H3,** I analysed 241 R&D alliances conducted by 107 companies from the CEE region in the years 2015-2017. To verify hypotheses, I used descriptive statistics and conducted a student's t-test analysis and a series of Pearson correlation analyses. The next section will present the results.

RESULTS AND DISCUSSION

Innovation cooperation with CEE and non-CEE partners in the biopharmaceutical industry in the CEE region

To verify the hypothesis assuming that companies in the biopharmaceutical industry in the CEE region are more likely to indicate the implementation of R&D alliances with CEE partners than with non-CEE partners, I performed a Student's t-test analysis. It showed the validity of the hypothesis, $t(106; N = 107) = 5.78; p < 0.001$. Table 1 presents the obtained results.

Table 1. Frequencies of identification of CEE and non-CEE partners in R&D alliances

Category	CEE partners (R&D alliances)	outside CEE partners (R&D alliances)
Number of indications (%)	97 (90.65%)	59 (55.14%)
Number of no indications (%)	10 (9.35%)	48 (44.86%)

Source: own elaboration.

Biopharmaceutical companies were more likely to indicate the implementation of R&D alliances with CEE partners (including domestic partners) than with non-CEE partners.

Considering the data presented in Figure 1, we may observe that the frequency of innovation cooperation with partners from CEE (n=97) and non-CEE (n=59) countries within R&D alliances in the biopharmaceutical industry in Central and Eastern European (CEE) countries was relatively low. The

average indications of companies collaborating with CEE and non-CEE partners oscillated between 'very rarely' and 'rarely' for customers, suppliers, companies from a different industry and competitors. Innovation cooperation with universities and research institutions within the framework of R&D alliances with CEE partners occurred 'rarely' and outside CEE 'very rarely'. In terms of R&D collaborations, companies 'occasionally' collaborated with pharmaceutical partners (both CEE and non-CEE partners) and 'rarely' with biopharmaceutical and biotech partners.
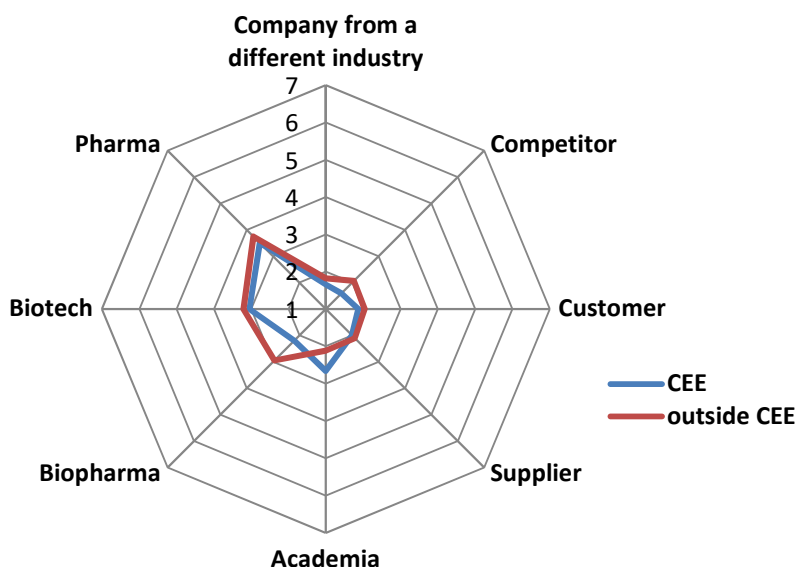

**Figure 1. Frequency of collaboration with CEE and non-CEE partners in research
and development (R&D) alliances in the biopharmaceutical industry in the CEE region**
Note: scale of 1-7, where: 1 – never, 2 – very rarely, 3 – rarely, 4 – occasionally, 5 – often,
6 – very often, 7 – most often (in 80% of cases). CEE n=97, outside CEE n=59.
Source: own elaboration.

To verify hypothesis **H1** that the frequency of cooperation within R&D alliances with CEE partners is higher than with non-CEE partners, I performed a Student's t-test analysis. This analysis showed that there were no significant differences between the two groups of partners, $t(47; N = 48) = 0.41$; *ni*. Table 2 presents the obtained results.

**Table 2. Descriptive statistics for the variables 'frequency of collaboration with CEE partners (R&D alliances)'
and 'frequency of collaboration with non-CEE partners (R&D alliances)'**

Variable	*M*	*N*	*SD*	*SE*
Frequency of cooperation with CEE partners (R&D alliances)	2.52	48	0.73	0.10
Frequency of cooperation with partners outside CEE (R&D alliances)	2.48	48	0.92	0.13

Source: own elaboration.

I conducted a series of Student's t analyses (*N* = 48) to verify hypothesis **H1** that the frequency of collaboration in R&D alliances with CEE partners is higher than that with non-CEE partners for selected sectors and partners. The results indicated that the hypothesis was valid for the selected partners: academia, supplier, customer, and sector: biotech. Figure 2 presents differences in the frequency of cooperation with CEE and non-CEE partners by sector and partner.

To verify hypothesis **H2** that the increase in the frequency of collaboration within research and development (R&D) alliances is significantly associated with an increase in a firm's R&D alliance success rate (SRA – success rate of alliances,[1] the percentage of R&D alliances in which partners achieved initial goals between 2015 and 2017) – while taking into account location of the partner/partners – I conducted a series of Pearson correlation analyses. The analyses showed that an increase in the frequency of R&D

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[1] Definition of SRA based on De Man and Duysters, 2007; De Man, Duysters, and Neyes, 2009; De Man *et al.,* 2012.

alliance collaboration was significantly associated with an increase in the success rate of a company's R&D alliances with international partners, $r = 0.44$; $p < 0.001$, partners outside CEE (non-CEE), $r = 0.41$; $p < 0.001$ and domestic partners, $r = 0.39$; $p < 0.001$. These correlations were of moderate strength. Finally, an increase in the frequency of R&D alliance collaboration was significantly associated with an increase in the success rate of a company's R&D alliances with partners from Central and Eastern Europe (CEE), $r = 0.29$; $p < 0.05$, while the strength of the correlation was weak. Table 3 shows the obtained results.
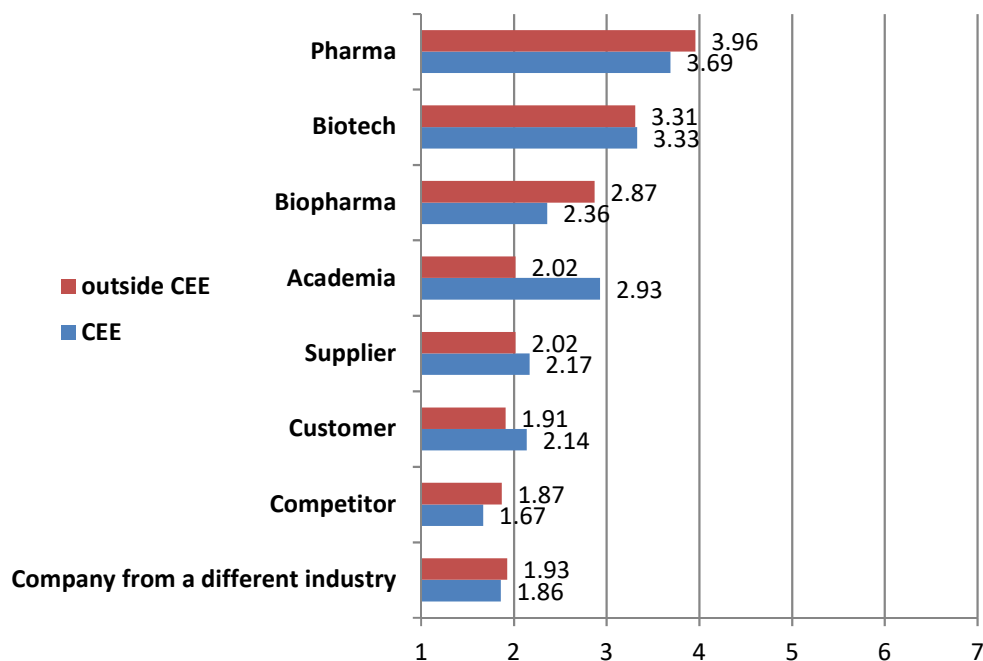
Figure 2. Differences in frequency of cooperation in R&D alliances between CEE and non-CEE partners (comparisons by partner and sector)
Note: scale of 1–7, where: 1 – never, 2 – very rarely, 3 – rarely, 4 – occasionally, 5 – often, 6 – very often, 7 – most often (in 80% of cases). (CEE n=97, outside CEE n=59)
Source: own elaboration.

Table 3. Relationship between the frequency of collaboration in research and development (R&D) alliances and the success rate of a company's R&D alliances with selected partners

The success rate of R&D alliances with		Frequency of cooperation in research and development (R&D) alliances
National partners (domestic)[a]	r	0.388
	p	0.000***
International partners[b]	r	0.435
	p	0.000***
CEE partners[c]	r	0.290
	p	0.023*
Non-CEE partners[d]	r	0.406
	p	0.000***

Note: [a] – N = 106; [b] – N = 83; [c] – N = 60; [d] – N = 73; * – p < 0.05; ** – p < 0.01; *** – p < 0.001.
Source: own elaboration.

Considering the implemented research and development (R&D) alliances in the biopharmaceutical industry, it is worth analysing the directions of innovation cooperation within the framework of international alliances implemented by companies from CEE countries. To verify hypothesis **H3** that the companies from the CEE region in the biopharmaceutical are more willing to develop R&D alliances with partners from the CEE region rather than with partners outside the CEE region (non-CEE) taking into account the direction of innovation cooperation, I analysed 241 R&D alliances conducted by 107 companies, implemented between 2015 and 2017. The following figures present the

individual directions of innovation cooperation for R&D alliances. Regarding partners from non-CEE countries, I grouped foreign partners into North America, Western Europe, and Asia. Given the larger number of R&D alliances implemented (241), I presented the results for the different country groups. I used abbreviations for countries to present the results more clearly. Moreover, the figures highlight companies that reported research and development (R&D) alliances with domestic partners in addition to international innovation collaborations.

Figure 3. Directions of innovation cooperation within international research and development (R&D) alliances in the biopharmaceutical industry in the Central and Eastern European countries in 2015-2017: Albania, Belarus, Bosnia and Herzegovina, Bulgaria
Note: * innovation cooperation within the framework of research
and development (R&D) alliances also with domestic partners.
Source: own elaboration.

Within the framework of R&D alliances, companies from Albania (AL), Belarus (BY), Bosnia and Herzegovina (BA), and Bulgaria (BG) (all CEE countries) (Figure 3) implemented international innovation cooperation in the biopharmaceutical industry between 2015 and 2017 with partners from Western Europe (five alliances), North America (four alliances), and Asia (four alliances). Furthermore, companies from Albania (AL), Belarus (BY), Bosnia and Herzegovina (BA), and Bulgaria (BG) also pursued innovation cooperation with domestic partners. A company from Albania (AL) also conducted international cooperation within the framework of R&D alliances with partners from CEE – Bulgaria (BG), Montenegro (ME), Kosovo (XK), Macedonia (MK), and Serbia (XS). In total, between 2015 and 2017, companies from Albania (AL), Belarus (BG), Bosnia and Herzegovina (BA), and Bulgaria (BG) conducted innovation cooperation within 29 R&D alliances in the biopharmaceutical industry.

Within the framework of research and development (R&D) alliances, companies from the CEE countries of Croatia (HR), the Czech Republic (CZ), Estonia (EE), and Hungary (HU) (Figure 4) most frequently implemented international innovation cooperation in the biopharmaceutical industry in 2015-2017 with partners from Western Europe (24 alliances), North America (seven alliances), and

Asia (four alliances). Moreover, companies from Croatia (HR), the Czech Republic (CZ), Estonia (EE), and Hungary (HU) also pursued innovation cooperation with domestic partners. Companies from Croatia realised international cooperation within R&D alliances with CEE partners from Poland (PL) and Slovenia (SI), companies from Estonia (EE) – with partners from Poland (PL) and Lithuania (LT), and from Hungary (HU) – with partners from Croatia (HR), Moldova (MD), Romania (RO), Serbia (XS), and Slovakia (SK). Companies from the Czech Republic (CZ) pursued international cooperation with partners from Hungary (HU), Poland (PL), and Slovakia (SK), and from Kosovo (XK) – with partners from Poland (PL). In total, between 2015 and 2017, companies from Croatia (HR), the Czech Republic (CZ), Estonia (EE), Hungary (HU), and Kosovo (XK) implemented innovation cooperation within 97 R&D alliances in the biopharmaceutical industry.

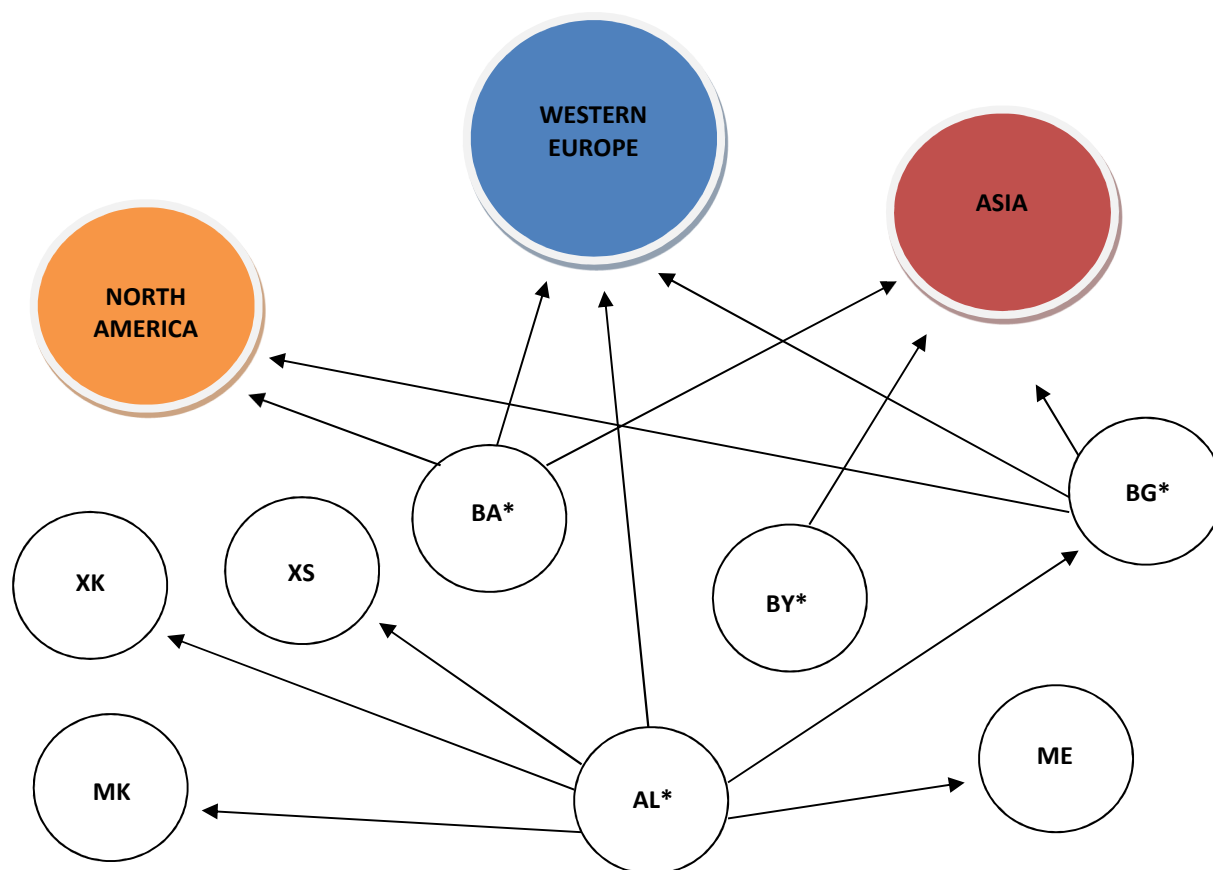**Figure 4. Directions of innovation cooperation within international R&D alliances in the biopharmaceutical industry in the CEE countries in 2015-2017: Croatia, Czech Republic, Estonia, Hungary, Kosovo**

Note: * innovation cooperation within the framework of research
and development (R&D) alliances also with domestic partners.
Source: own elaboration.

Within the framework of R&D alliances, companies from the CEE countries of Lithuania (LT), Latvia (LV), Macedonia (MK), Serbia (XS), and Slovenia (SI) (Figure 5) implemented international innovation cooperation in the biopharmaceutical industry in 2015-2017 with partners from Western Europe (seven alliances), North America (one alliance), and Asia (one alliance). Furthermore, companies from Lithuania (LT), Latvia (LV), Macedonia (MK), Serbia (XS), and Slovenia (SI) also pursued innovation cooperation with domestic partners. Companies from Latvia (LV) cooperated internationally within R&D alliances with CEE partners from Estonia (EE), Lithuania (LT), Serbia (XS), Slovakia (SK), and Slovenia (SI), while companies from Lithuania (LT) – with partners from Estonia (EE) and the Czech Republic (CZ). Companies from Macedonia (MK) cooperated internationally with partners from Bulgaria (BG) and Serbia (XS), and companies from Serbia (XS) – with partners from Slovenia (SI). Companies from Slovenia (SI) pursued international cooperation with partners from Hungary (HU), Poland (PL), and Serbia (XS). In total, between 2015 and 2017, companies from Lithuania (LT), Latvia (LV), Macedonia (MK), Serbia (XS), and Slovenia (SI) conducted innovation cooperation within 33 R&D alliances in the biopharmaceutical industry.
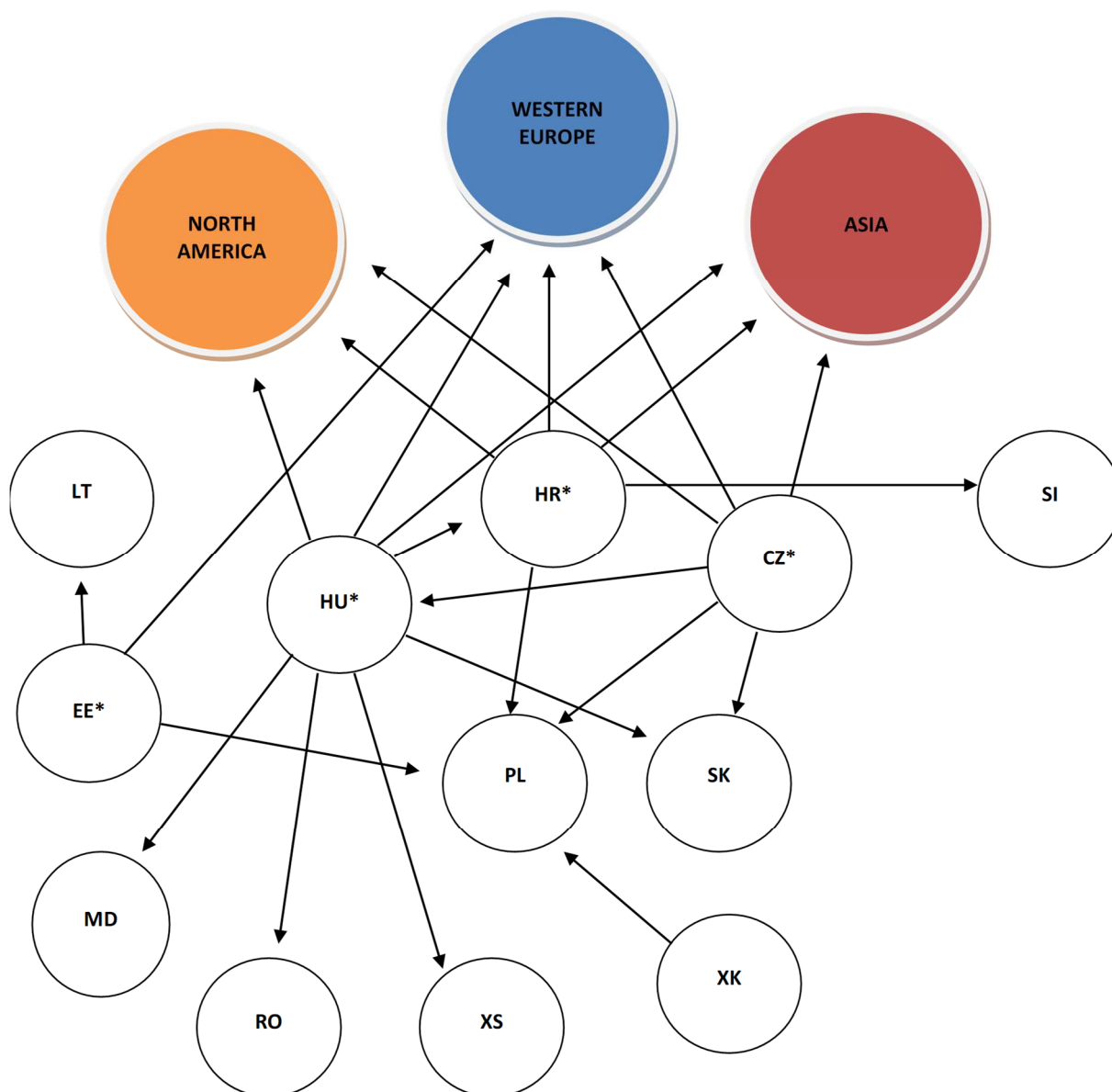

Figure 5. Directions of innovation cooperation within international R&D alliances in the biopharmaceutical industry in the CEE countries in 2015-2017: Lithuania, Latvia, Macedonia, Serbia, Slovenia
Note: * innovation cooperation within the framework of research
and development (R&D) alliances also with domestic partners.
Source: own elaboration.

Within the framework of R&D alliances, companies from the CEE countries of Lithuania (LT), Latvia (LV), Macedonia (MK), Serbia (XS), and Slovenia (SI) (Figure 5) implemented international innovation cooperation in the biopharmaceutical industry in 2015-2017 with partners from Western Europe (seven alliances), North America (one alliance), and Asia (one alliance). Furthermore, companies from Lithuania (LT), Latvia (LV), Macedonia (MK), Serbia (XS), and Slovenia (SI) also pursued

innovation cooperation with domestic partners. Companies from Latvia (LV) cooperated internationally within R&D alliances with CEE partners from Estonia (EE), Lithuania (LT), Serbia (XS), Slovakia (SK), and Slovenia (SI), while companies from Lithuania (LT) – with partners from Estonia (EE) and the Czech Republic (CZ). Companies from Macedonia (MK) cooperated internationally with partners from Bulgaria (BG) and Serbia (XS), and companies from Serbia (XS) – with partners from Slovenia (SI). Companies from Slovenia (SI) pursued international cooperation with partners from Hungary (HU), Poland (PL), and Serbia (XS). In total, between 2015 and 2017, companies from Lithuania (LT), Latvia (LV), Macedonia (MK), Serbia (XS), and Slovenia (SI) conducted innovation cooperation within 33 R&D alliances in the biopharmaceutical industry.

Figure 6. Directions of innovation cooperation within international R&D alliances in the biopharmaceutical industry in the CEE countries in 2015-2017: Poland, Romania, Slovakia, Ukraine

Note: * innovation cooperation within the framework of research
and development (R&D) alliances also with domestic partners.
Source: own elaboration.

Within the framework of R&D alliances, companies from the CEE countries of Poland (PL), Romania (RO), Slovakia (SK), and Ukraine (UA) (Figure 6) most frequently implemented international innovation

cooperation in the biopharmaceutical industry in 2015-2017 with partners from Western Europe (15 alliances), North America (nine alliances), and Asia (four alliances). Moreover, companies from Poland (PL), Romania (RO), and Slovakia (SK) also pursued innovation cooperation with domestic partners. Companies from Poland (PL) implemented international cooperation within R&D alliances with CEE partners from Bulgaria (BG), Bosnia and Herzegovina (BA), Croatia (HR), the Czech Republic (CZ), Estonia (EE), Hungary (HU), Lithuania (LT), Latvia (LV), Macedonia (MK), Romania (RO), Serbia (XS), Slovakia (SK), Slovenia (SI), and Ukraine (UA). Companies from Romania (RO) conducted international cooperation with partners from Hungary (HU), and companies from Slovakia (SK) – with partners from the Czech Republic (CZ). In total, between 2015 and 2017, companies from Poland (PL), Romania (RO), Slovakia (SK), and Ukraine (UA) conducted innovation cooperation within 82 R&D alliances in the biopharmaceutical industry.

Between 2015 and 2017, CEE companies pursued international innovation collaborations in the biopharmaceutical industry through 89 R&D alliances with non-CEE partners, including 51 alliances with Western European partners, 21 alliances with North American partners, and 17 alliances with Asian partners. Furthermore, companies pursued innovation cooperation in 152 R&D alliances with CEE partners (including 93 alliances with domestic partners and 59 alliances with international partners from CEE countries). The countries most involved in innovation cooperation were Poland with 56 R&D alliances (including 22 alliances with non-CEE partners, 18 with domestic partners, and 16 with partners from CEE countries), Hungary with 40 alliances (including 15 alliances with non-CEE partners, 17 with domestic partners, and 8 with partners from CEE countries), from the Czech Republic with 36 alliances (including 15 with partners from outside CEE, 13 with domestic partners and 8 with partners from CEE countries), Romania with 18 alliances, and Croatia and Bulgaria with 16 alliances. In total, companies from CEE countries pursued 241 R&D alliances in the biopharmaceutical industry in innovation cooperation between 2015 and 2017.

Considering the direction of innovation cooperation within R&D alliances of CEE companies in the biopharmaceutical industry, we can observe that the CEE companies are more willing to develop cooperation with CEE and domestic partners (easier to cooperate due to closer location) than with non-CEE partners. Thus, I can confirm that the partner's location is an important determinant in the development of innovation cooperation in the CEE region. The reason for that can be the specifics of the CEE region, in which the companies are still not so open to international cooperation, especially in the biopharmaceutical industry, and prefer to develop cooperation with local and domestic partners. Moreover, we can still observe a lot of barriers in innovation cooperation between companies, as well as in business-academia cooperation in the CEE region, which include: lack of trust, language barriers, problems with knowledge transfer (both on company/institutional level), the problem with mentality in the CEE (the difficult experience. of communism), the problem with opening-up to the cooperation of business representatives with universities, lack of funds for the development of innovation cooperation (public/private) with business and academia, and the overall low frequency of innovation cooperation with different partners (also identified in this research).

CONCLUSIONS

The main aim of this study was to verify the importance of location in innovation cooperation in the biopharmaceutical industry in the CEE region, taking into account the frequency of cooperation within R&D alliances with CEE partners and with non-CEE partners, as well as the directions of cooperation within R&D alliances. As it was one of the first such studies presented in the literature, we may treat the study results as exploratory. To verify the directions of cooperation within R&D alliances in the biopharmaceutical industry, I investigated 241 R&D alliances conducted by 107 companies from the CEE region in the years 2015-2017. The results showed that the frequency of cooperation within R&D alliances with CEE partners was higher than with non-CEE partners (for selected partners: academia, supplier, customer, and sectors: biotech), as well as the number of indications. Moreover, according to the analysis of 241 R&D alliances, I also observed that the companies from the CEE region are more willing to develop R&D alliances with partners from the CEE region (including partners from the domestic market) than with partners outside the CEE region (North America, Western Europe, Asia) in

the biopharmaceutical industry. Comparing the results with the previous literature while taking into account R&D alliances in the biopharmaceutical industry in the CEE region, I can confirm a preference for geographically close partners (domestic or in the CEE region) in addition to a preference for known partners (Li *et al.*, 2008; Reuer & Lahiri, 2014, Narula & Martínez-Noya, 2015; Martínez-Noya & Narula, 2018). However, the frequency of innovation cooperation in the CEE region is low.

Noteworthy, taking into account the success rate of alliances (SRA) (% of R&D alliances in which initial goals were achieved between 2015 and 2017), the CEE companies had a better success rate within R&D alliances with domestic partners (n=48) – around 54% than with international partners (n=48) – around 47%, and non-CEE partners (n=48) – around 43%. I observed the lowest success rate of R&D alliances (SRA) for the CEE companies with partners from the CEE region (n=48) – around 37%. Taking that into consideration, we can see that CEE companies have better SRA for international R&D alliances with international and non-CEE partners than with CEE partners. On the other hand, the CEE companies try to use local potential in the development of innovation cooperation in the biopharmaceutical industry in domestic markets. We could observe it very well especially during the Covid-19 pandemic (Puślecki *et al.*, 2022). An example includes the 'ECMO for Wielkopolska Programme' implemented in the Wielkopolska Region in Poland. Moreover, in the last two years, we have observed the development of governmental initiatives, *e.g.* Warsaw Health Innovation HUB (WHIH) in Poland, which aims to integrate innovative companies from the biopharmaceutical industry with research institutions and universities, as well as state institutions such as ABM (Medical Research Agency) (Schuh, Trąpczyński & Puślecki, 2024).

As in any scientific study, it is important to mention the problems and limitations associated with the implementation of the study. Among the main problems and limitations, we may indicate:

− the difficulty in obtaining companies to participate in primary research in the 18 CEE countries and the extended time of data collection: the primary quantitative survey took a total of 15 months;
− in primary research, the CEE companies were reluctant to agree to participate in the survey, explaining it with lack of time for such activities and the confidentiality of the information provided (due to the specific nature of the biopharmaceutical industry) along with the requirement to share data on innovation cooperation;
− the small sample size (n=107) with a varying number of entities in individual CEE countries (no equal groups), which may have blurred the phenomenon of innovation cooperation, which is why I analysed the entire CEE region rather than individual countries. Comparisons between countries are still possible and could be a new very interesting research avenue;
− the small sample size (n=107): I cannot generalise the results obtained from the quantitative studies conducted for the whole population.

In these difficult times of the Covid-19 pandemic, companies, especially in the biopharmaceutical industry, should be more open to innovation cooperation (Wilks, Porthmann, 2012; Chesbrough, 2020; Puślecki, 2021; Bourla, 2022) and use more flexible models (Puślecki, 2012; Wilks & Prothmann, 2012). Moreover, they should use local potential and local partners in the development of better therapies for patients (Puślecki, 2021; Puślecki *et al.*, 2022). Over 80% of companies (n=107) from the biopharmaceutical industry from 18 CEE countries conducted mainly R&D non-equity alliances (which provide greater flexibility in the selection and possible change of partners and also enable a faster change/exchange of technology than traditional equity alliances) in the development of innovation cooperation in years 2015-2017. With more flexible modes of cooperation, companies can deliver new solutions and better patient treatment to the market faster, which is particularly germane to responses to the current Covid-19 pandemic and potential future pandemics.

Involving all partners from the local, regional, and national levels, both from business and academia in the innovation cooperation can positively impact the innovation cooperation performance (Trąpczyński, Puślecki & Staszków, 2018). The identified directions of innovation cooperation in CEE countries may contribute to the development of innovation cooperation in CEE countries in the future and greater exploitation of the innovation and educational potential of the biopharmaceutical industry in the

entire CEE region (clinical trials, clusters, science and technology parks, academia, institutions) (Staszków, Puślecki & Trąpczyński, 2017; Drelich-Skulska & Jankowiak, 2019; Puślecki, 2021; Puślecki *et al.*, 2022).

Given the potential research and new research areas, it is certainly worthwhile to conduct further research in the CEE countries on the innovation cooperation in the development of new medical technologies and devices (Digital Health, MedHealth) (especially during the Covid-19 pandemic), the use of modern medical simulation (translational simulation, translational innovation) and technologies (virtual reality, augmented reality, big data, blockchain, artificial intelligence, collaborative AI, machine learning, deep learning, cloud computing) in the development of new therapies and treatments for patients (Śliwiński & Puślecki, 2022; Puślecki *et al.*, 2022), the exploitation of the potential of clinical trials in the CEE region, and cooperation in the management of patient and drug data (storage, processing and recombination of data aiming to develop new drugs and therapies proposals for patients). It is also worth comparing the development of such collaboration in the CEE region with other emerging regions, *e.g.* Middle East and North Africa (MENA; Alhajaj & Moonesar, 2023; Kumar *et al.*, 2022a, b; Moonesar & Dass, 2021).

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Conflict of Interest

The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

The regional environment of smart organisations as a source for entrepreneurship development in the EU

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A B S T R A C T
Objective: The objective of this article is to investigate the relationship between the wealth of the regional environment of a smart organisation and the entrepreneurship level, based on examples of EU regions.
Research Design & Methods: This article is based on a quantitative, cartographic analysis combined with a critical analysis of the literature on the subject. Using the method of linear ordering of standardised summary data based on data for European regions, an innovative model of smart IT resources, knowledge and relationships were developed to study their impact on the development of entrepreneurship and innovative enterprises. The model was tested for three groups of firms: in general aggregation, groups engaged in product innovation, and groups engaged in business innovation. The study covered data for 240 regions from 22 EU member states.
Findings: The literature lacks a clear definition and measurement methods for smart organizations. The most important resources for their development are relational, IT, human and Research and Development capital, which are also crucial for modern companies. There is no correlation between a region's prosperity and overall entrepreneurship, but there is a clear link between high potential for smart organization development and smart business development. Research shows a link between innovative enterprise development and IT, relational capital and scientific research capital.
Implications & Recommendations: Smart organizations in innovative environments drive socioeconomic development through technological entrepreneurship and digital equivalents of traditional products and services. Digitalization of the economy through smart organizations is crucial for micro and meso-level competitive advantage. To identify key mechanisms, public statistics must be adapted to the needs of the digital economy.
Contribution & Value Added: This article proposes measuring the relationship between regional potential for smart organizations and entrepreneurship, with a new methodology and approach to support regional management in digitalization. It highlights that IT, human, and research and development capital are key factors for entrepreneurship, and offers a new definition of entrepreneurship. The article also identifies a research gap in the theory of locating innovative enterprises.
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INTRODUCTION

Entrepreneurship is one of the most important determinants of economic development because of its impact on employment, innovation, and productivity. For the development of entrepreneurship, the environment in which firms are created and operate is of great importance. This environment consists of tangible elements (*e.g.*, firms and infrastructure), intangible elements (*e.g.*, skills and knowledge),

and institutions, including, for example, power at various levels. This authority can actively shape the conditions for startups and strengthen pro-entrepreneurial attitudes.

This is especially important in the VUCA environment, *i.e.*, volatility, uncertainty, complexity, and ambiguity (Bennett & Lemoine, 2014), in which companies currently operate. Furthermore, the ongoing globalisation and related scientific and technological advances are leading to changes in the perception and manifestations of entrepreneurship, which requires a change in the approach of public administration to promote entrepreneurship. Under these new conditions, public administration units operating at different levels (regional, local, national) are looking for ways to improve their activities, which consist in meeting the needs of local development actors, including, for example, entrepreneurs and investors. One such way is the smart organisation of the public sector, which can help to better adapt to ongoing changes and take advantage of opportunities that arise, for example, in the technological field. The research in this article was conducted at the regional level in the EU.

According to Florida (1995), regions must learn by attracting resources and then organising them. The endowment of the region with resources (capital) conducive to the creation of regional intelligent organisations can influence the possibility of promoting the creation and development of modern enterprises. Therefore, the aim of the article was to investigate the relationship between the wealth of the regional environment of a smart organisation and the level of entrepreneurship, using EU regions as an example. The level of entrepreneurship was understood as the number of entrepreneurs registered in the REGON register in the area of local government units (Derlukiewicz *et al.*, 2021). Noteworthy, there are no studies in the literature on the relationship between the wealth of the regional environment of smart organisations and the level of entrepreneurship in the region. This indicates a knowledge gap that this study attempts to fill. Moreover, the article identifies a methodological gap in the literature regarding the definition and measurement of a smart organisation in the region, so this study will provide a proposal to fill this gap.

The study attempted to answer the following research questions:

1. How is a smart organisation defined in the region and what are its features and metrics?
2. What are the main resources (potential) required for the development of smart organisations in the region?
3. What are the relationships between the resources of the regional environment of smart organisations and the level of entrepreneurship?

The first part of the study will present the definitions of smart organisations in the region and the existing methods of measuring smart organisations in the region based on the methods of measuring smart cities. The next part of the study will identify the current conditions for the development of entrepreneurship in the context of new approaches to the definition of this phenomenon, followed by a look at the research method used. The results of the research will be then presented and discussed, and the article will end with the conclusions drawn from the conducted research.

LITERATURE REVIEW AND HYPOTHESES DEVELOPMENT

Definitions of Smart Organisation and Their Specificity in The Public Sector Organisation and Regional Environment Context

An early predecessor of the smart organisation is the learning organisation pertaining to the ability to create, acquire, and transfer knowledge within its boundaries, and an ability to modify organisational behaviour in a way reflecting knowledge and insights (Garvin, 1993).

Information and the ability to use it in the right way at the right time started to become perceived as the competitive advantage of an enterprise, and thus, knowledge management, as a domain in both scholarly and real economy contexts, gained importance. A specific type of learning organisation, one advancing and mastering organisational learning ability, is an ambidextrous organisation and it is characterised by the parallel between two types of learning, *i.e.*, exploitative learning enabling to improve and advance existing organization's capabilities and resources and exploratory learning oriented on

monitoring the organizational environment and identification and acquisition of relevant new insights and knowledge (He & Wong, 2004).

According to Yolles (2006), organizational processes related to self-awareness of the organization's condition, within the context of acquiring new knowledge for competitiveness, are crucial differentiating factors among intelligent, ambidextrous, and learning organization types.

Compared to learning organizations, smart organizations exhibit a greater emphasis on a clearly defined purpose and the stakeholders they serve, utilize feedback loops to enhance learning, and employ technology solutions for data analysis and operations. According to scholars, smart organisations are knowledge-driven, interworked, and dynamically adaptive organisational forms, which practice learning and agility to stay customer-focused and to master change and uncertainty (Filos & Banahan, 2001). Filos (2006) indicates that smart organizations define their activities based on knowledge and they exploit the knowledge to respond to concrete market opportunities within the reach of the organization. Other scholars outline that smart organisations highly depend on the customer's feedback and organise tasks linked to specific processes and goals to respond to both dynamic patterns of consumers' needs and expectations and workers' skills and availability (Iapichino et al., 2018).

The most recent definitions of smart organisations highlight the importance of monitoring the organisational environment and operations, creating collaborative networks that enhance reactive and proactive organisational capabilities, and leveraging technological and human resources to become sustainable in the environmental, economic, and social aspects (Sousa et al., 2020). Smart organisations are also defined through a combination of expertise provided by human resources with the support offered by technology-based platforms (Adamik & Sikora-Fernandez, 2021).

To summarise, smart organisations prioritize a clearly articulated organizational purpose that goes beyond mere existence or survival, depend on relevant organisational stakeholders' feedback, exploit existing organisational knowledge to leverage the ability to fulfil the organisational purpose, explore new, non-existing organisational knowledge to serve relevant organisational stakeholders, are dynamically adaptive, adopt an interworking approach, use collaborative and leveraging support of technology-based solutions and other tools for purposeful utilisation of information and data for its operations.

The smart organisation, compared to the type of smart organisations studied for over three decades in managerial and engineering sciences (Lopez-Roblez et al., 2019), is more oriented on the purpose, the stakeholders it serves, and the feedback loops it uses to enhance learning. It also uses technology in data analysis and operations, which is an aspect we can attribute to this specific organisation type.

The public sector, which is the context of smart organisations in this article, consists of entities owned and reporting to the state, local and regional self-governments, or self-government entities, in which most of the ownership and equity can be attributed to public entities. By its nature, the public sector focuses primarily on satisfying the needs and legal entitlements of the stakeholders its serves, rather than the economic profits. In this article, we focus on public sector organisations responsible for governance over given local and regional administrative-territorial units and the provision of defined public goods and services.

Therefore, a smart organisation in the public sector should be directed towards satisfying the needs of the local development stakeholders it serves, such as residents, investors and entrepreneurs, and other features related to the nature of the public sector. The smart organisation analysed in this article derives from its location in a concrete environment and the resources it possesses within that environment, which influence the development potential and maturity level smart organisations demonstrate. Wereda (2010) defines a smart organisation in the public sector as an organisation providing employees with education and skills improvement opportunities, searching for effective and innovative sources of finance, implementing changes to respond to market megatrends, and encouraging new economic entities and residents to settle in its territory by leveraging its brand and local government fiscal and financial incentives, leveraging education and the skills of its citizens.

Moreover, scholars outline the capacity of smart organisations in the public sector to generate and manage knowledge, including its utilization in executing public tasks, by being creative and innovative in problem-solving, capable of forecasting social needs, and flexible in responding to them (Sikora-Fernandez, 2013). One of the discursive definitions of smart organisations in the public sector defines

it as an organisational way of working within public sector units that effectively manage information, knowledge, communication, and relations with partners, leverage technology to deliver upon public tasks, and dynamise local development processes to achieve and maintain competitive advantages (Godlewska-Majkowska & Komor, 2019).

This definition directly highlights the importance of relational, IT, and human capital as key resources needed to develop smart organisations in the region. Indirectly, this definition emphasises the role of scientific and research capital in the development of smart organisations in regions, because it creates knowledge in the region, is an institution that trains personnel, for example for public administration, and is an important partner that collaborates with public administration to drive development processes in a given area. It can be concluded that among the most important resources (potential) required for the development of smart organisations in the region, the following are particularly important: relational, IT, human, and research and development capital, which are the answer to the second research question, and were analysed in the empirical part of this article at the regional level in the EU.

Existing Methods of Assessing Smart Organisation in The Public Sector Organisation and Regional Environment Context

The popularisation of the phenomena of smart cities and smart municipalities in the last decade in the European Union raises the question of whether and to what extent smart organisations in the public sector overlap with them. Smart cities are defined through the specific capability to utilise information and communication technologies to increase citizens' quality of life. Smart cities are often discussed within the context of urban planning and governance, where technology solutions play a crucial role in collecting, processing, and utilizing data from various municipal networks and installations. These installations can include parking spaces, traffic lights, water supply systems, sewers, and public monitoring systems. The aim of incorporating technology in this manner is to enhance and improve urban planning, urban management, and governance practices (Jiang *et al.*, 2018).

The initial focus of smart city initiatives investigated by the OECD related to the usage of digital information and communication technologies to improve the efficiency of urban services planning and delivery. Later, the debate started to include the effects of smart city initiatives on residents, the environment, and the local development model (OECD, 2020). The smart city definition in the European Union introduced by the European Commission accentuates their higher efficiency of leveraging traditional networks and services through the usage of digital and telecommunication technologies for the benefit of residents and businesses (European Commission, 2014).

The concept of the smart city is a continuously evolving subject of debate and a smart organisation in the public sector as defined in this article can contribute to it, especially within the context of the organisational purpose of a smart organisation over technology, orientation on educated and informed decision-making, dynamisation of local development processes, and an increase in local competitiveness and attractiveness for its development stakeholders. Smart organisations in the public sector in the context of their measurement approaches refer to smart city measurement methods defined within the subject matter literature.

The approach introduced by the Centre of Regional Science, Vienna University of Technology, (2007) is based on a set of 74 statistical indicators clustered in six areas including smart economy, smart people, smart governance, smart mobility, smart environment, and smart living. Another smart organisation measurement method is based on original indicators consisting of statistical sub-indicators in the domains of economy, human capital, governance, mobility, environment, and quality of life (Szczech-Pietkiewicz, 2015).

The CITYkeys framework developed by the European Commission (2016) focuses on smart organisation measurement through data categories of people, planet, prosperity, governance, and promotion. It contains output indicators (*e.g.*, the number of open data sets) and impact indicators (*e.g.*, reduced energy consumption). The framework contains a set of multiple indicators, as well as details of data availability, sources, reliability, and accessibility. The CITYkeys approach harmonises quantitative and qualitative data gathered through interviews. One of the most popular measurement approaches was developed by IMD-SUTD (International Institute for Management Development and Singapore University of

Technology and Design, 2017) in the form of the Smart City Index (SCI), which assesses the perceptions of residents of cities in a survey on issues related to two pillars, *i.e.* structures and technology applications available to them in their city (1), and existing city infrastructure (2). Each pillar is evaluated over five key areas: health and safety, mobility, activities, opportunities, and governance.

The United Nations initiative introduced a novel smart sustainable cities measurement approach 'The United for Smart Sustainable Cities (U4SSC)' (2017), which focused on a diverse set of cities' performance indicators in economy, society, and environment dimensions aimed at assessing smartness and sustainability aspects, including usage of ICT, physical infrastructure, social inclusion, and equity aspects in access to public services, quality of life, environmental and cultural needs of the population.

The most recent approaches in the measurement of smart organisations in the public sector include original indicators based on 43 public statistics sub-indicators structured with the preference ranking organisation method for enrichment evaluations (PRO METHEE method) (Ogrodnik, 2020) and the comprehensive framework of the OECD (2020). Analysis of smart organisations in public sector measurement methods indicates the growing importance of digitisation and connectivity (The Economist Group, 2022). The investigated smart cities measurement methods interconnect with the smart organisation definition elaborated earlier, although the former set of definitions is more quantitative in its approach to data format collection and does not comprise aspects typical for a smart organisation.

Smart city measurement methodologies are also the subject of scholarly discourse on their limitations and relate to a vast number of measurement indicators. A literature review of smart city indicators identified 1152 different smart city indicators (Petrova-Antonova & Ilieva, 2018).

Based on analysis of reviewed scholar and professional domain measurement approaches of intelligent organisations, smart organisations, and smart cities, a research gap in the measurement of smart organisations in the public sector was identified with a proposal to address this gap being the subject of the next parts of this article. A specific methodological gap identified relates to the lack of a method of measurement of correspondence between smart organisations and the entrepreneurship activities it enables and fosters in its environment. The link between a smart organisation in public sector organisations and the entrepreneurship it potentially enables and fosters is a key research phenomenon investigated in this article.

Why Do Enterprises Need to be Smart?

Entrepreneurship is a complex, multifaceted phenomenon, variously defined and classified in the literature, which evolves and creates new forms and types of behaviour. Entrepreneurship is an important factor in economic prosperity, influencing the level of economic development of regions and countries.

Nowadays, in thinking about the concept of entrepreneurship, great importance is given to the role of relational capital. Thus, Blundel and Lockett (2011) emphasize that entrepreneurship involves a complex pattern of social interactions that extends beyond individual entrepreneurs to incorporate teams, organizations, networks, and institutions. Evolutionary economics also draws attention to the role of relational capital in the development of entrepreneurship and emphasizes the importance of human capital, IT capital, and indirectly also scientific and research capital. Hence, according to Malerba and McKelvey (2020), entrepreneurship is a process with emergent properties, involves actors searching for opportunities and generating new knowledge, is affected by the learning, technological and knowledge context, involves the co-evolution of knowledge, firms, industrial structure and institutions. Using the conceptual framework of Malerba and McKelvey, a study was conducted to consider the implications of IT, human, scientific-research, and relational capital for entrepreneurship, which are contemporary conditions for the development of entrepreneurship. At the same time, it is worth noting that these conditions were the main resources (potentials) necessary for the development of smart organizations in the region, which was shown in the previous part of the article.

The development of entrepreneurship is influenced by many internal and external factors. External factors include the broad economic environment, the globalization process, and related scientific and technological progress, including advancing digitalization. This environment is changing in a turbulent and rapid manner (VUCA world), and in recent years the dynamics of these changes have accelerated, leading to an increase in risks and uncertainties both in starting new enterprises

and in running a business. Current experiences, such as the coronavirus pandemic, the war in Ukraine, rising inflation, and the climate and energy crisis increase uncertainty and make it necessary to overcome obstacles to business survival and development. It is believed that the uncertainty of the environment, resulting among other factors from the Covid-19 pandemic, has enabled a better understanding of the importance of the ability of various organizations, including enterprises, to keep up with digital innovation and the need to change business models to survive in the market (Coskun-Setirek & Tanrikulu, 2021).

There are many studies in the literature that analyse the impact of IT capital on entrepreneurship, *e.g.*, in the context of the need to move from conventional ways of working to more digitised methods to increase the chances of market success and achieve a higher efficiency level (Dima, 2021; Haaker *et al.*, 2021). Digital technologies promote entrepreneurship because, firstly, digitalisation changes entrepreneurship and the process of creating new economic entities, and secondly, digital technological innovations create new entrepreneurial opportunities. Moreover, digital technologies contribute to the creation of new businesses in the digital industry (Sahut *et al.*, 2021). The use of digital technologies makes it possible to increase efficiency (*e.g.*, by reducing costs, saving time, reducing downtime, training employees) and create new business models (*e.g.*, platform-based Airbnb, Uber, skill share, prosumption, etc.) (Strømmen-Bakhtiar, 2019; Ibarra *et al.*, 2018).

In light of the literature, entrepreneurship is often defined as the process of identifying, evaluating and exploiting entrepreneurial opportunities (Schumpeter, 1934; Shane & Venkatraman, 2000; Shane 2003) by applying innovative solutions to create new value (Brown & Ulijn, 2004). Today, this process is strongly dependent on human capital, including the internal knowledge of entrepreneurs (prior knowledge, experience, creativity, cognitive processes, etc.) and/or the search for and acquisition of information by entrepreneurs from external sources, such as social networks (Shu *et al.*, 2018). The importance of human capital in the development of entrepreneurship is also confirmed by The Timmons model of the entrepreneurial process, in which the founder, team, and resources play a key role in addition to opportunities (Spinelli & Adams, 2011). This confirms the role of human capital in creating entrepreneurial processes, while challenging changes in education – both at the higher education level and in lifelong learning – in global entrepreneurial skills. Studies conducted in China show that entrepreneurship education in universities improves the ability to start a business in the present and to engage in entrepreneurial activities in the future (Lv *et al.*, 2021).

Nowadays, the important feature of development is the intellectualisation of enterprises and the degree of science intensity of the organisation, as an adaptation to the requirements of the knowledge-based economy. Intellectual competence has the potential to enhance entrepreneurship (Abosede & Onakoya 2013). Therefore, knowledge-intensive innovative entrepreneurship is defined as new innovative firms that have significant knowledge intensity in their activity, are embedded in innovation systems, and exploit innovative opportunities in diverse evolving sectors and contexts (Malerba & McKelvey, 2020). The increasing importance of knowledge in entrepreneurial activity influenced the creation of the concept of intellectual entrepreneurship, which emphasises the links between entrepreneurship, intellectualism, and academia (Johannisson *et al.*, 2011). Therefore, the issue of teaching entrepreneurship at the university level is widely analysed in the literature, as well as the role of universities in creating innovations and transferring knowledge to the economy (*e.g.*, in the context of spin-off company creation, technology transfer, science parks, incubators, and university-industry relations) (Guerrero *et al.*, 2016; Gubik, 2021).

In the conditions of a constantly changing environment, the functioning of a company based on relational capital and cooperation with other entities creates opportunities to achieve a sustainable competitive advantage (Corvino *et al.*, 2019) which a single enterprise, especially a small or medium-sized enterprise (SME), cannot achieve. This approach is also supported by the concept of clusters (Porter, 1990). Entrepreneurship involves establishing relationships with actors that provide opportunities to transform knowledge resources into innovations (Abosede & Onakoya, 2013). Research demonstrates the significant role of relational capital in the establishment of new businesses (Hormiga *et al.*, 2011). Furthermore, there exists a positive correlation between relational capital and indicators of firm resilience (Matos *et al.*, 2022), innovation capacity, and efficiency of small and medium-sized

enterprises (Sulistyo, 2016). Moreover, relational capital has been linked to the innovativeness of products developed by SMEs (Dorrego *et al.*, 2013). Research also shows that highly entrepreneurial small firms tend to create entrepreneurial business networks and use them effectively to achieve sustainable outcomes (Abbas *et al.*, 2019). In manufacturing companies, reliability and information exchange can positively impact the supply chain and reduce its risks (Afshar & Fazli, 2018).

In conclusion, a new definition of entrepreneurship was proposed based on literature studies. Nowadays, entrepreneurship can be defined as a complex process of social interactions between different actors that generates new knowledge and exploits the opportunities that arise in a changing environment with a VUCA character, through knowledge, learning, experience, information search, and the use of advanced technologies (including digital) in business to create new values for stakeholders and to undertake innovative activities that are created, *e.g.*, in collaboration with research and development units.

These prior empirical results allowed us to assume the following research hypotheses:

H1: Smart organization in the region is an ambiguously defined and measured concept in the literature.

H2: There is a relationship between the wealth of the regional environment of a smart organisation and the entrepreneurship level.

H3: The level of innovative entrepreneurship shows a stronger relationship with the wealth of the regional environment of a smart organization compared to entrepreneurship in general.

RESEARCH METHODOLOGY

For a review of smart organizations' definitions and measurement methods, a systematic literature review (SLR) was applied. The review process included review design, literature search in Web of Science, Scopus, and Directory of Open Access Journals databases, literature screening after elimination of duplicated and non-English language papers, and papers with no fit to the topic of smart organizations, and finally literature analysis. The literature search resulted in 656 papers identified in the period 2002-2022, 95 of which were selected for deep reading and reporting. Synthetic results of SLR were presented in the literature review and hypotheses development subchapter on smart organization definitions and measurement methods.

The study aimed to investigate the relationship between the wealth of the regional environment of a smart organization and the entrepreneurship level, using EU regions as examples. To evaluate the relationship between smart organizations in local governments and the development of entrepreneurship in European regions, eight indicators were used, each representing one of the four capitals: human, IT, research and development, and relational capital (Figure 1). The factors influencing the development of enterprises, including innovative enterprises, are complex and multifaceted, and their measurement requires the inclusion of various indicators describing the smart potential in local governments. The difficulty in measurement is translating theoretical assumptions into measurable empirical indicators that describe a particular phenomenon. The area we selected for building the model of business development potential includes regions in Europe. The choice of indicators resulted from the literature studies conducted in the previous part of the paper, which highlighted the current conditions for entrepreneurship development and was conditioned by the availability of statistical data at the regional level in the EU.

Data for 240 regions from 22 EU Member States, Norway, Serbia, Switzerland, and the United Kingdom at different NUTS levels were used for the study. The availability of data at NUTS levels varied, so the collected indicators covered 47 NUTS 1 regions and 193 NUTS 2 regions. In the EU Member States Cyprus, Estonia, Latvia, Luxembourg, and Malta, the NUTS 1 and NUTS 2 levels are identical to the national territory, so in this case, the national level was included. The selection of indicators took into account both the broad technological potential of IT and human potential, especially digital skills and human resources for the use of modern technologies in economic and social structures (Table 1).
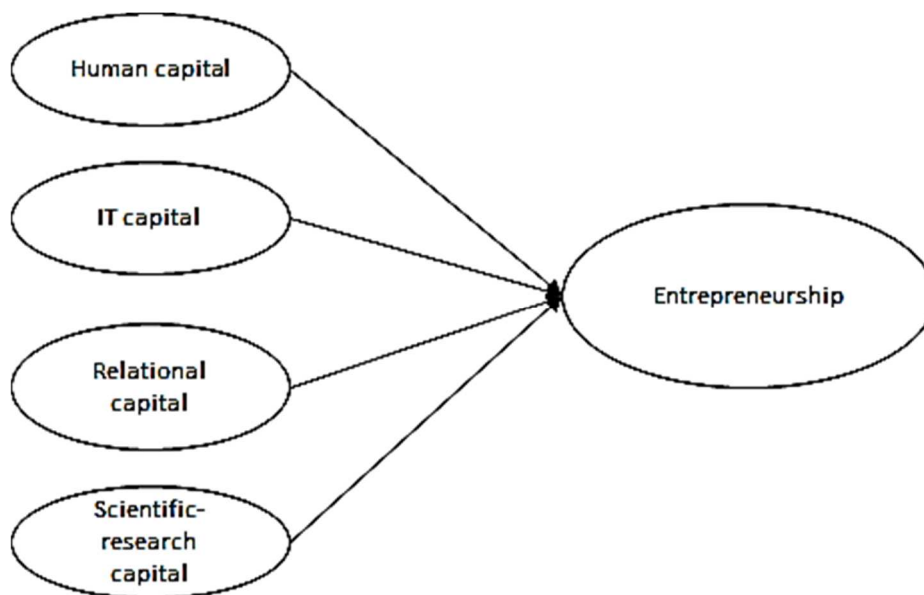
**Figure 1. Resources of the regional environment
of a smart organization and entrepreneurship**
Source: own elaboration.

An evaluation of individual capitals was conducted to create an assessment of European regions using the standardized sums method. The selection of indicators took into account the assumptions of the concept of smart organizations and their institutional, social, and technological dimensions. The indicators were standardized and then grouped, which allowed a statistical description for each capital. Since the research aimed to identify the potentials of regions and spatial regimes, the model indicators were assigned the same weights. The process of preparing the assessment of regions for smart development included the implementation of the following activities: defining capitals; selecting empirical characteristics; standardising variables; calculating zero-sum of unitization for capitals; grouping units of the studied population by groups of capitals; evaluating the consistency of indicator structure (k-means classification).

The level of capital was evaluated by the method of linear ordering of the standardized total data. The procedure starts with standardization by normalizing the one-dimensional variables according to the following formula:

$$x_{ij}' = \frac{x_{ij} - x_{minj}}{x_{maxj} - x_{minj}} 100 \tag{1}$$

in which:

j - next function number,

i - next spatial unit number,

x_{ij}' - normalized feature j in the spatial unit i,

x_{ij} - the value of the feature j in the spatial unit i.

Based on the normalized variables, a vector of the normalized sums of the ratios of the individual capitals is determined. A synthetic index of the potential of a smart organization (IOP) is created as an arithmetic average of the normalized characteristics corresponding to the individual objects, where m is the number of indicators, according to the formula:

$$IOP = \frac{1}{m} \sum_{j=1}^{m} x_{ij}' \tag{2}$$

Table 1. Potentials (resources) of the regional environment of a smart organization used in the analysis

Capital	Indicator	Characteristic	Year	Source of data and year
Human capital	X1 Population with tertiary education	Number of people with post-secondary education aged 25-34 in relation to the total number of inhabitants aged 25-34	2019	Eurostat, regional statistics 2019
	X2 Lifelong learning	Number of people aged 25-64 in households who participated in at least four weeks of education or training in relation to the age group 25-64	2019	Eurostat, regional statistics
IT capital (digitization)	X3 Digital skills	Number of people with over basic general digital skills in the areas (information, communication, problem-solving, content creation) in relation to the age group 16-74	2019	Regional Innovation Scoreboard 2021
	X4 ICT specialists	Number of employed ICT specialists who are competent to develop, operate and maintain ICT systems and it is the main part of their work to the total number of employees	2019	Regional Innovation Scoreboard 2021
Relational capital	X5 Innovative SMEs collaborating with others	Number of SMEs operating under innovation cooperation. with other enterprises or institutions in relation to the total number of enterprises	2018	Eurostat
	X6 Public-private co-publications	Number of public-private scientific publications co-authors with both domestic and foreign collaborators in relation to the number of inhabitants	2020	Regional Innovation Scoreboard 2021
Scientific-research capital	X7 International scientific co-publications	Number of scientific publications with at least one co-author living abroad in relation to the number of inhabitants	2020	Regional Innovation Scoreboard 2021
	X8 Most-cited publications	Number of scientific publications among the 10% most cited publications in the world in relation to the number of scientific publications	2018	Regional Innovation Scoreboard 2021
Entrepreneurship	Y1 Number of business entities	Number of economic entities entered into the REGON system	2018	Eurostat
Innovative enterprise	Y2 Product process innovators	Number of small and medium-sized enterprises (SMEs) that have introduced at least one product innovation in relation to the total number of enterprises	2018	Eurostat
	Y3 Business process innovators	Number of small and medium-sized enterprises (SMEs) that have introduced at least one business process innovation that is either new to the enterprise or new to its market	2018	Eurostat

Source: own elaboration.

RESULTS AND DISCUSSION

In relation to the results of SLR performed on smart organizations definitions, a variety of propositions was identified, often overlapping with other organizational concepts such as learning organization, ambidextrous organization, and intelligent organization. Our research also allowed us to propose a well-fitting definition of a smart organization in the context of the public sector within a regional environment. This contribution extends to the theoretical development of smart organizations. In reference to methods of smart organizations measurement, a set of various approaches was identified ranging from scholar domain to professional domain approaches, including proliferating in recent years smart city concept. The identified measurement methods did not relate to enablers and emerging factors of smart organizations. We addressed the gap through a methodological contribution of the empirical research method proposed in the research methodology section.

The obtained results of the spatial distribution of the synthetic potential indicator for smart organizations can be combined with the economic regions of Europe and the level of their economic development (Figure 2). These are mainly the regions of Great Britain, Sweden, Finland, Switzerland,

the Netherlands, Germany, Sweden, and the capitals of their functional areas. These are areas of high migration activity. Residents from other regions and immigrants flock to the capital in the hope of a better job and the possibility of a higher standard of living. As a result, these cities grow very quickly and the urban space must be constantly adapted to population changes. The relatively lowest values of the indicator are found in post-communist countries, such as Poland, Romania, Bulgaria, and Hungary, as well as in Western Europe, Spain, and Portugal. These are the fastest depopulating regions in Europe, for which demographic changes pose a serious challenge. This process is the result of intra-EU migration to economically more developed regions. Moreover, there is a phenomenon of drainage, *i.e.*, the acquisition of highly qualified human capital. As a result of constant emigration, the 'sending regions' lose highly qualified people to the 'receiving regions,' which are more industrialized and economically developed. Another problem is the low fertility rate, which, coupled with the increasing average life expectancy, causes European regions to age demographically.
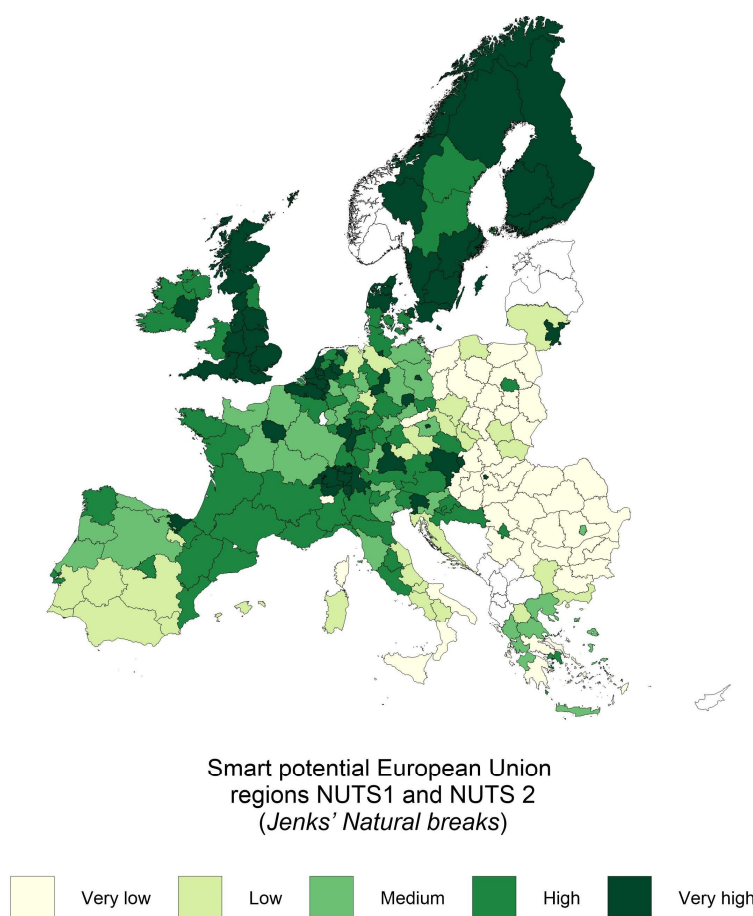

Smart potential European Union
regions NUTS1 and NUTS 2
(*Jenks' Natural breaks*)

| Very low | Low | Medium | High | Very high |

Figure 2. Smart organizations' development potential (IOP)

Note: The study used data from 240 regions from 22 EU Member States, Norway, Serbia, Switzerland and the United Kingdom at different NUTS levels. Data availability for NUTS levels varied, hence the collected indicators cover 47 NUTS level 1 regions and 193 NUTS level 2 regions. In the EU Member States, Cyprus, Estonia, Latvia, Luxembourg and Malta, the NUTS level 1 and NUTS level 2 are the same as the national territory and therefore national levels are included.
Source: own elaboration.

The developed model was used to examine the relationship between the potential of smart regions and the presence of innovative enterprises. Due to the lack of data for some countries and regions, they were excluded from the co-occurrence study. The obtained results indicate a positive correlation of the studied indicators, which means that high values of the model parameters are accompanied by high values of the dependent variables. However, in the case of potency, there are significant differences for individual indicators, which are presented below.

Table 2. Pearson's correlation matrix[1]

Variable		x1	x2	x3	x4	X5	X6	X7	X8	IOP	y1	y2	y3
1. x1	Pearson's r	−											
	p-value	−											
2. x2	Pearson's r	0.449***	−										
	p-value	1.400e-12	−										
3. x3	Pearson's r	0.393***	0.745***	−									
	p-value	9.483e-10	4.087e-41	−									
4. x4	Pearson's r	0.582***	0.462***	0.439***	−								
	p-value	8.412e-22	2.647e-13	4.905e-12	−								
5. x5	Pearson's r	0.347***	0.485***	0.592***	0.375***	−							
	p-value	8.840e-8	1.080e-14	1.227e-22	6.325e-9	−							
6. x6	Pearson's r	0.467***	0.512***	0.565***	0.638***	0.600***	−						
	p-value	1.368e-13	2.042e-16	2.093e-20	4.187e-27	2.170e-23	−						
7. x7	Pearson's r	0.547***	0.529***	0.521***	0.618***	0.578***	0.944***	−					
	p-value	6.136e-19	1.352e-17	4.580e-17	3.968e-25	1.899e-21	3.281e-109	−					
8. x8	Pearson's r	0.298***	0.560***	0.659***	0.375***	0.637***	0.665***	0.630***	−				
	p-value	5.471e-6	5.406e-20	2.151e-29	6.404e-9	5.135e-27	4.610e-30	3.007e-26	−				
9. IOP	Pearson's r	0.659***	0.768***	0.795***	0.728***	0.750***	0.866***	0.862***	0.770***	−			
	p-value	2.233e-29	4.523e-45	2.266e-50	1.977e-38	7.455e-42	3.906e-69	1.020e-67	2.541e-45	−			
10. y1	Pearson's r	0.338***	0.148*	-0.009	0.359***	0.088	0.204**	0.246***	0.171*	0.247***	−		
	p-value	2.110e-7	0.027	0.895	2.917e-8	0.191	0.002	1.961e-4	0.010	1.796e-4	−		
11. y2	Pearson's r	0.267***	0.178**	0.236***	0.624***	0.296***	0.527***	0.413***	0.217**	0.448***	0.281***	−	
	p-value	4.832e-5	0.007	3.662e-4	1.175e-25	6.386e-6	1.692e-17	1.060e-10	0.001	1.700e-12	1.917e-5	−	
12. y3	Pearson's r	0.057	0.391***	0.553***	0.296***	0.723***	0.586***	0.484***	0.595***	0.596***	0.047	0.336***	−
	p-value	0.395	1.268e-9	2.125e-19	6.318e-6	1.070e-37	4.187e-22	1.238e-14	6.014e-23	4.553e-23	0.485	2.464e-7	−

Note: [1] Regions excluded from the analysis: EL41 Voreio Aigaio, HR02 Panonska Hrvatska, HR05 Grad Zagreb, HR06 Sjeverna Hrvatska, RS11 Belgrade, RS12 Vojvodina, RS21 Šumadija and Western Serbia, RS22 Southern and Eastern Serbia, CH01 Région lémanique, CH02 Espace Mittelland, CH03 Nordwestschweiz, CH04 Zürich, CH05 Ostschweiz, CH06 Zentralschweiz, CH07 Ticino.
Significant codes: * p < 0.05, ** p < 0.01, *** p < 0.001.
Source: own elaboration.

The relationship between high values of potential for the development of smart organizations and the development of intelligent enterprises is noticeable. It was found that the synthetic indicator of potentials for smart IOP organizations is weakly correlated with the number of enterprises $r = 0.247$, $p < 0.001$, moderately correlated with the number of enterprises introducing product innovations $r = 0.448$, $p < 0.001$ and strongly correlated with the number of enterprises introducing business innovations $r = 0.596$, $p < 0.001$.

This confirms hypothesis H3: The level of innovative entrepreneurship shows a stronger relationship with the wealth of the regional environment of a smart organization compared to entrepreneurship in general. In the case of hypothesis H2, a strong relationship between the wealth of the regional environment of a smart organization and the level of general entrepreneurship was not confirmed.

In the case of enterprises introducing product innovations, a strong relationship was found with the X4 index – the percentage of employed ICT specialists in the total number of employees, $r = 0.624$, $p < 0.001$, and the X6 index public-private scientific publications, $r = 0.527$, $p < 0.001$ (Figure 3).

In the case of enterprises introducing business innovations, a strong relationship was found with the X3 digital skills inhabitants, $r = 0.553$, $p < 0.001$, X5 innovative SMEs collaborating with others, $r = 0.723$, $p < 0.001$, X6 public-private co-publications, $r = 0.586$, $p < 0.001$, X7 international scientific co-publications, $r = 0.484$, $p < 0.00$ and X8 most-cited publications, $r = 0.595$, $p < 0.001$ (Figure 4).
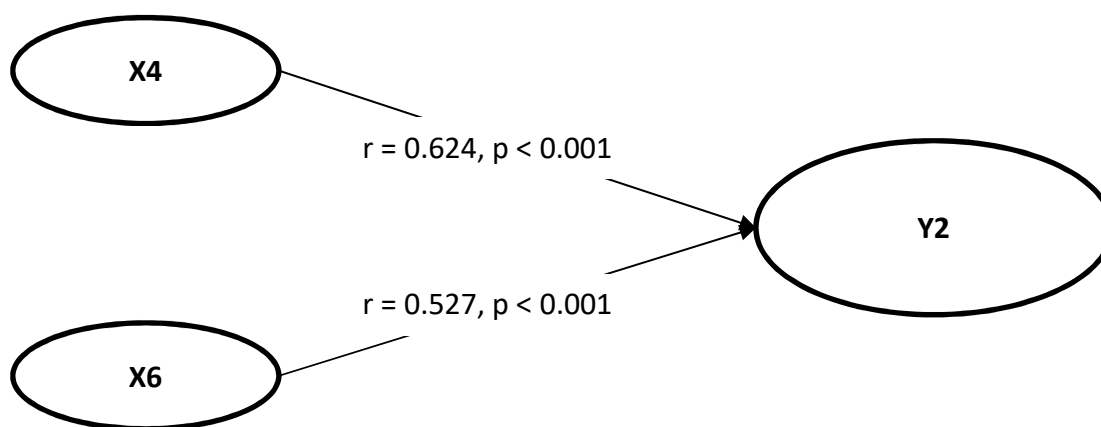

Figure 3. Model of variables for enterprises introducing product innovations
Source: own elaboration.

The obtained results can be referred to similar studies in which multivariate comparative analyses and ranking of regions were conducted. Statistical models of competitiveness have a practical dimension and a significant impact on the development of regional strategies and policies from a socio-economic perspective. An example of such a study is the EU regional competitiveness index initiated in 2010 and published by European Commission. The concept of regional competitiveness (RC) has found interest among both academics and policymakers and is a frequently cited and widely used index. It aims to measure the region's ability to offer companies and residents an attractive environment to live and work in (Dijkstra *et al.*, 2011). It is an important tool that provides a European perspective on the competitiveness of regions based on 68 indicators. The index deserves attention because of the opportunities it offers to assess and compare regions regardless of the political context. It examines the ability of regions to create growth and jobs based on three main categories of factors affecting competitiveness: economic potential, innovation, and infrastructure and business environment conditions. The latest 2023 RCI release uses a fully revised methodology and recalculated the previous two editions. RCI 2.0 consists of three sub-indicators 'basic,' 'efficiency' and 'innovation' and 11 pillars dealing with different aspects of competitiveness: 'institutions,' 'macroeconomic stability,' 'infrastructures,' 'health,' 'basic education,' 'higher education, training, and lifelong learning,' 'labour-market efficiency,' 'market size,' 'technological readiness,' 'business sophistication,' and 'innovation.' The report indicates, among other things, that the growth of innovation is crucial for improving the competitiveness of EU regions. Regions that invest in R&D and have well-developed innovative sectors tend to be more competitive (Dijkstra *et al.*, 2023).
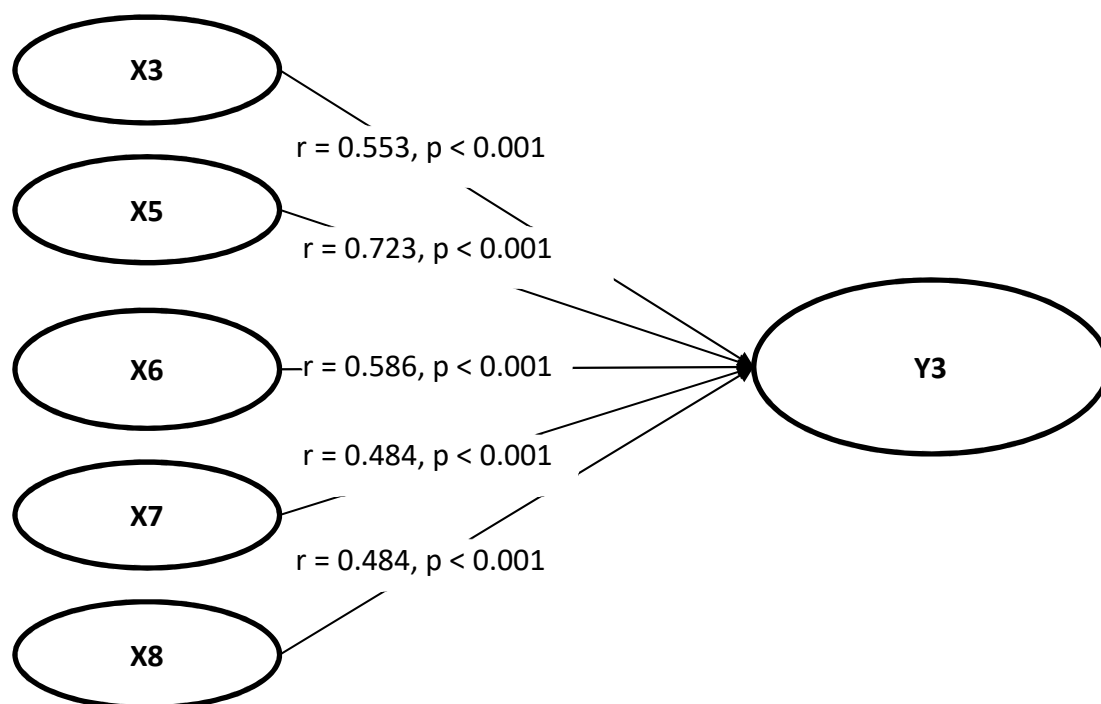
Figure 4. Model of variables for enterprises introducing business innovations
Source: own elaboration.

The second hypothesis we put forward assumed that there is a relationship between the richness of the regional environment of an intelligent organization and the level of entrepreneurship. It has been confirmed only partially, because enterprises have their specifics of functioning and not all require the involvement of new information technologies and specialized skills. Today, a large group of companies can grow despite regional deficits in digital skills and access to knowledge. These are most often sectors of the economy based mainly on traditional services and production. This group also includes enterprises and professions that, despite the development of IT technology and artificial intelligence, will not be threatened by technological substitutability shortly. These are primarily those activities in which social intelligence and high roots in social relations play a key role. Therefore, in the context of IT technology, it is currently difficult to find strong relationships between the development of entrepreneurship in general and human capital. Most European regions are in transition and the effects of the new digital revolution and economic transformation are still to come. This is also confirmed by the 2022 RCI 2.0 Competitiveness Survey of European Regions, which shows large differences in the competitiveness of European regions. The polycentric pattern prevails, with good results in regions where large urban areas are located. However, the difference between the capital city region and the other regions varies between EU Member States, with more competitive countries tending to have a smaller difference between their capital region and other regions, as well as fewer internal disparities (Dijkstra *et al.*, 2023).

On the other hand, hypothesis 3 was confirmed. It assumed that the level of innovative entrepreneurship has a stronger relationship with the richness of the regional environment of a smart organization compared to entrepreneurship in general. Innovative enterprises are more likely to demonstrate the characteristics of smart enterprises and can tap into the regional potential of IT-oriented human capital and knowledge and innovation transfer. Our research indicates that regional conditions play the greatest role in the case of business innovations, which are responsible, among other things, for organizational processes in the company and are based on human and relational capital. Interestingly, in the case of product innovations, we found a connection with only two regional factors in the form of access to IT specialists and cooperation in the field of scientific research. In the case of product innovations, joint research work conducted by private companies and public sector researchers seems

to be crucial. Our observations can be related to similar results of other studies by Malerba and McKelvey (2020), according to which IT technologies, human capital, scientific research, and relational capital are contemporary conditions for the development of entrepreneurship and the main resources (potentials) necessary for the development of smart organizations in the region. The conclusion is that the regional environment of smart organizations is a source of entrepreneurial development in the EU. This is particularly true for companies capable of absorbing and exploiting regional competitive advantages in terms of technology and knowledge.

CONCLUSIONS

The article aimed to examine the relationship between the wealth of the regional environment of a smart organization and the entrepreneurship level using EU regions as an example.

The starting point for the considerations was the classification of key terms. The identified definitions of smart organisations indicated the presence of ambiguities in the perception of the essence of this phenomenon and the development of the necessary characteristics of this type of organisation. Regardless of whether they are non-spatial or spatial, smart organisations exhibit the characteristics of learning and ambidextrous organisations. A newly-perceived aspect is the association of smart organisations with competitive advantages based on better information and knowledge management than their competitors. Moreover, smart organisations include stakeholders that both act as co-creators of these organisations and benefit from the effects of their existence. The aspect of competitiveness and the open nature of smart organisations is important for all types of smart organisations, whether they are business or spatial in nature. Therefore, we can positively confirm hypothesis H1 in the part related to the ambiguity of the definition of a smart organisation.

Thus, smart organisations are a phenomenon that is very difficult to measure. The difficulty arises both from the selection of characteristics that describe a smart organisation and from the selection of appropriate indicators that adequately describe it. There is a plethora of measurement methods proposed by scholars and practitioners, but they rarely refer to attributes that characterise smart organisations in the context of local and regional development. Therefore, we can positively confirm hypothesis H1 regarding the second part, which refers to the ambiguity of measurement methods.

We also see the need to formulate a new definition of entrepreneurship. Nowadays, entrepreneurship can be defined as a complex process of social interactions between different actors that generates new knowledge and exploits the opportunities that arise in a changing VUCA environment, through knowledge, learning, experience, information search, and the use of advanced technologies (including digital) in business to create new values for stakeholders and to undertake innovative activities that are created, *e.g.*, in collaboration with research and development units. This provides broader opportunities for interpreting research results, especially in relation to technological entrepreneurship. However, for spatial research purposes, it is necessary to limit observations to simple measures, as statistical data systems cannot keep pace with the rapidly growing digital economy. It is particularly difficult to perform such analyses in a comparable manner for regions located in different countries, even if they are members of the European Union. The problem with the availability of statistical data is the most important research limitation.

Smart organisations evolve according to changes in their external environment, new technologies and their diffusion, and the specifics of each region's path of development. Based on literature studies, it has been shown that the main resources required for the development of smart organisations in the region are IT, human, research, and relational capital, which is the answer to the second research question. The above aspects are also the current conditions for entrepreneurship development. Therefore, searching for a relationship between the wealth of the regional environment of a smart organisation and the entrepreneurship level using the EU regions as an example, we proposed measures of a synthetic nature corresponding to each regional capital and referring to the necessary characteristics of smart organisations.

Because of the application of the method of linear ordering of the standardised sum values based on data for the European regions, we can conclude that there is no evidence of a relationship between

the wealth of the regional environment of a smart organisation and the entrepreneurship level. Therefore, hypothesis H2 could not be confirmed. On the other hand, the relationship between high values of regional potential for the development of smart organisations and the development of smart enterprises is clearly evident and is the basis for confirming the validity of hypothesis H3. At the same time, it provides the basis for a deeper investigation of this relationship in relation to technological entrepreneurship or the smartification of production and services.

The reasons for this phenomenon lie in the slow process of transformation of traditional enterprises into smart and innovative ones, with the development of entrepreneurship determined by both internal and external factors. Entrepreneurship is a complex and multifaceted phenomenon and the variability of the conditions in which it operates forces it to constantly adapt and find new and competitive solutions.

Today, entrepreneurship should be characterised by the ability to innovate in uncertain times and to act intelligently in the market, recognising and taking advantage of opportunities that arise in its environment. To fulfil these functions, the company needs intelligent management resources that are different from the traditionally perceived factors of production. A new dimension in which companies are increasingly moving and conducting their activities is the digital infrastructure they use to collect and process large amounts of data. Together with the decision-making process, they create a dimension of intelligent organization, resistant or adapting to the changing environment. The relationship between the level of intelligence of a local government unit and the intensity of development of individual innovative entrepreneurship undertaken in this article is also important from the point of view of the development of location theory. Until now, the location of innovative enterprises has been explained through innovation theory and network theory, which is reflected in the concept of the triple helix as a theoretical foundation explaining the location decisions of innovative enterprises.

In the context of creating a digital economy, there is a dearth of examples illustrating how local or regional governments can create locational values that meet the new spatial needs of innovative enterprises.

New business models have a blurred spatial structure, which results from 1/ virtualization of business activity (digital products and services with supra-regional reach, digital twins, remote or hybrid work) 2/ accelerated open and at the same time network spatial structures of innovative enterprises directly from the first phase to the fifth phase of the Larry Greiner organization development cycle as a result of the spread of remote work and the development of sales platforms.

It causes the blurring of the spatial layout of companies without a clearly defined spatial structure of both the company itself and its markets. An example of this can be innovative enterprises developing on the basis of crowdfunding, prosumer behaviour, and cooperation, also based on B2B models. In view of the rapid changes in both the structures of innovative enterprises and the virtualization of public services offered by local government units, there is a need to indicate new dimensions of the location environment, important when making decisions regarding the place of registration and the place of business activity by innovative enterprises.

The research shows that regions with high development potential for intelligent organizations are a favourable environment for innovative enterprises, among which IT resources, human, research, and relational capital stand out.

The conducted research shows that today not only digital technologies, but also employees who can use these technologies in their daily work are important for companies. Fast and collective learning develops the human and organisational capital of a company. In particular, the presence of IT workers in the region and their movements in the regional labour market contribute to the development of innovative companies. In this context, smart entrepreneurship can be defined as the process of organising and conducting business activities and assuming the associated risk based on IT resources, large data sets, and computer algorithms.

In addition to the internal company factors already mentioned, the social environment is also important. Digital competencies and a high level of digital literacy are not a universal phenomenon and there are still gaps in computer and software skills in various social groups. This is a factor that can slow down the development of the digital economy, where most processes and activities are

conducted virtually through websites and various types of utilities. Digital skills also increase the chances of developing new entrepreneurship in local communities, as the Internet has expanded the unlimited possibilities of knowledge acquisition in its various dimensions. Users of new technologies can access information channels, reports, and lectures, and participate in many online meetings without having to physically move. All of this together creates new value and breaks down the barriers to accessing knowledge in entrepreneurship development.

The study also confirmed the link between the regional level of scientific research and research personnel and the development of innovative businesses. The presence of universities and research institutions in the region is a key element of innovation systems, as innovation requires collaboration, while competitive strategies do not allow entrepreneurs to fully participate in the processes of sharing sensitive strategic data that represent competitive advantages. The role of universities and research institutes is therefore to act as knowledge brokers by expanding collaboration in R&D research and developing new solutions for businesses.

These elements of the development potential of intelligent organizations are not a simple sum of accumulated elements, because of the synergy between individual components. Therefore, further research is required to identify mechanisms supporting the creation of locations of key elements of spatial structures of innovative enterprises, especially at the initial stages of innovation diffusion.

The last but very important issue to consider in the research is the growing importance of cybersecurity, the use of artificial intelligence, and related ethics and data collection and use. Digital technologies opened a new chapter in social relations by allowing us to record our behaviour and preferences and obtain sensitive data. Corporate social responsibility will therefore be responsible for how this data is used in business practice, as there is a fine line between an information society and a surveillance society. The task of new technologies, intelligent machines, and organisations is therefore sustainable development, in which quality of life is an overriding value.

Each of these research strands is a difficult research field at the regional level due to the problem with the availability of statistical data.

Creating a favourable locational environment for innovative enterprises and entrepreneurship in general requires measures to strengthen the resilience of territorial self-government units to shocks. The basis is the creation of the evolution of regions in accordance with the concept of smart city or smart village 4.0. It may also be helpful to create a basis for monitoring socio-economic development based on open databases on regions in accordance with international standards, *e.g.* ISO/CD 37123 Sustainable development in communities – Indicators for Resilient Cities.

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What works and what does not work
in local entrepreneurship support policy?

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A B S T R A C T
Objective: The article aims to determine the influence of specific entrepreneurship support instruments in each type of municipality on the increase entrepreneurship level as measured by the number of newly established companies in the area.
Research Design & Methods: A survey was conducted among 896 Polish municipalities, asking about four areas of entrepreneurship support: cooperation of the commune with entrepreneurs; finance, tax, and administration support; attracting investors, granting external funds by the commune; and supporting non-governmental organizations. To determine the relationship between the type of commune, the instrument used, and the effectiveness of the tool used, we used a generalized reduced gradient non-linear algorithm.
Findings: The study results proved that there is no one universal area or instrument that would guarantee with high probability success in the form of an increase in the level of entrepreneurship in a municipality, regardless of its type. It was shown that in specific types of municipalities, it is possible to identify tools that are more effective than others.
Implications & Recommendations: This knowledge can and should provide important guidance to decision-makers at the local level, showing tools that may work better in their type of municipality.
Contribution & Value Added: The identification of specific tools that work for a particular type of municipality is an important stimulus in the discussion on strengthening the effectiveness of Polish municipalities' policies.

Article type:	research article
Keywords:	entrepreneurship; support instruments; municipal entrepreneurship; local development; local government support
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INTRODUCTION

Entrepreneurs are key actors in the process of stimulating development, because they introduce new technologies, creatively combine resources, and commercialize innovations, thus creating jobs, stimulating economic growth, and generating tax revenues (Lombardi & Sforzi, 2016; Müller, 2016 after Audretsch & Keilbach, 2005; Fritsch & Mueller, 2008; Isenberg, 2019; OECD, 2019; Rodrigues & Franco, 2021). There is a common view in the literature that local communes should play a key role in supporting the development of entrepreneurs in their jurisdictions (Bjørnå & Aarsæther, 2010; Madzivhandila & Musara, 2020; Municipal Role in Private Sector Development, 2004; Thekiso, 2016) while supporting selected directions, *e.g.* those related to sustainable development (Srinivas, 2022). Communes are the regulators and creators of the framework for the functioning of business entities, as they have a specific catalogue of instruments to support entrepreneurship.

At the same time, a kind of repetitiveness can be noticed in the activities of communes, which remain unchanged, despite the fact that researchers question whether local decision-makers analyze

the effectiveness of the solutions they implement or whether they apply them only because they are in the portfolio of forms of support available to local governments (Brooks *et al.*, 2019; Skica & Rodzinka, 2021). The literature review shows a multidimensional approach to the issue of supporting entrepreneurship at the local level. Publications concerning countries other than Poland treat the local context with reference to specific types of areas, such as small and medium-sized towns, comparing them to the conditions of creating entrepreneurship in the metropolis (for more, see Audretsch *et al.*, 2015, Naldi *et al.*, 2020, Pagano *et al.*, 2020, Audretsch & Feldman, 2004).

Researchers identify differences between local development initiatives and their employment effects depending on the type of commune (Olsson *et al.*, 2020). Audretsch *et al.* (2015) emphasize that policymakers identify the relationship between entrepreneurship and economic development, but little is known about how this relationship changes over time in cities with different market sizes. Olsson *et al.* (2020) justify that urban communes may have more resources for entrepreneurship management than rural communes, because they have been developing much faster for a longer period.

Brooks *et al.* (2019) show that in the case of Poland, there are aspects of the entrepreneurial ecosystem that go beyond the direct scope of public policy, undermining the view that the entrepreneurial ecosystem framework is an easy-to-implement public policy solution to stimulate entrepreneurship and business growth.

Although theoretical considerations of entrepreneurial support instruments used by communes are quite common in the literature, these studies do not present a cause-and-effect approach that could provide a basis for inference for policymakers at the local level. Thus, we have identified a research gap related to the need to assess the effectiveness of the use of these tools in communes, taking into account the type of commune. The three-level structure of Poland's territorial division (16 voivodeships, 314 powiats, and 2477 communes, including 302 urban, 66 cities with powiat rights, 662 urban-rural, and 1513 rural communes) translates into a diverse number and scope of public tasks (more in Mickiewicz *et al.*, 2016; Skica & Rodzinka, 2020). The specific gap is determined by the belief that depending on the type of commune and the predominant nature of activities in the area (agricultural, production, services), there are different possibilities and infrastructural, organizational, and financial needs to address in the development processes. This is consistent with, for example, the views of Thurik (2008), according to whom a properly selected instrumentalization of support has a chance to strengthen development effects, which will allow for reducing unnecessary expenses for activities that do not translate into support for entrepreneurship, and finally will contribute to highlighting local competitive advantages. Reviewing the measures taken and their effects seems particularly important in the face of rapid technological progress and the change in the way both the public and economic sector entities operate due to the Covid-19 pandemic.

On this basis, we designed a survey that covered 896 Polish communes (36% of all the communes in Poland). The study aimed to determine the impact of the application of specific activities lying on the side of entrepreneurship support instruments in the various types of communes on the increase in the level of entrepreneurship as measured by the number of newly established companies in their areas.

We assessed the activities carried out by communes in the field of local entrepreneurship development in four areas:

1. Cooperation between the commune and entrepreneurs (informing communes interested in setting up a company about available forms of financial support, organizing trainings, cooperating with local business environment institutions, outsourcing of municipal services).
2. Finance, taxes, and administration (the use of lower rates in local taxes, as well as the introduction of reliefs, exemptions, and tax remissions for people starting a business).
3. Attracting investors and external funds by the commune (marketing activities, advertising the commune outside, assistance in finding free land or premises, assistance in recruiting and training employees, promoting the commune's offer at foreign fairs, setting up a unit in the office for servicing foreign investors).
4. Supporting non-governmental organizations (providing free premises for statutory activities, providing materials and equipment, promoting non-governmental entities operating in the field

of public benefit, providing assistance to non-governmental organizations in establishing national and international contacts).

Showing specific relationships between the type of commune, the entrepreneurial support tools it uses, and its level of entrepreneurship can provide important implication material. On this basis, representatives of communes of a given type, can choose instruments to be implemented. The analysis will also expose whether these so-called 'soft' instruments chosen by communes affect the level of local entrepreneurship.

To study the dependence, among others, generalized reduced gradient (GRG) non-linear algorithm was used, which made it possible to arrange communes in terms of supporting entrepreneurship in a way that ensures obtaining the maximum value of the tau-Kendall coefficient. Furthermore, Kruskal-Wallis test was conducted, which at the same time enables to assess the degree of influence of individual areas of a communes' activity on supporting local entrepreneurship.

This article is comprised of the following sections. The first section will focus on the theoretical background. The second section will delineate the methodology for the quantitative empirical analysis. This will be followed by the key section of the study, which will detail the obtained research results. The study will end with a section devoted to the discussion, practical implications, limitations, and future research on the subject.

LITERATURE REVIEW AND HYPOTHESES DEVELOPMENT

The literature review was divided into two complementary sections. Their layout aims to provide substantive argumentation necessary to formulate research hypotheses. The first section will refer to the relationship between the generic category of a commune and the establishment of companies. Similarly to cities, rural communes are places of business location (Bański, 2016), but their specificity affects the different characteristics of companies established in their area (Bosworth, 2012; Henderson, 2002) and affects the differences in the forms of supporting entrepreneurship (Naldi *et al.*, 2020). As a result, business creation in rural and urban areas has different characteristics (Henderson *et al.*, 2007; Renski, 2008). Municipalities are much better equipped with infrastructure for business (Korsgaard *et al.*, 2015), supporting the creation of a network of cooperators, which allows them to consume the benefits of location (Frenkel, 2001; Van Geenhuizen & Nijkamp, 2009). Location decisions are therefore crucial from the perspective of establishing companies and well-chosen instruments to stimulate them can significantly strengthen this potential (Skica & Rodzinka, 2021; Porter & Stern, 2001). The condition is entrepreneurial intentions, which are expressed in effect (Sarasvathy, 2008), which is in line with the idea of bricolage (Baker & Nelson, 2005). This relationship is also indicated by Rod and Rod (2020). The demonstrated diversification of commune features and patterns of establishing companies specific to them justifies the study of the relationship between entrepreneurship and the type of commune. Although Bosma and Sternberg (2014) prove that entrepreneurship (particularly motivated by opportunity) is usually higher in urban areas, Renski (2008) shows that rural areas are also characterized by high rates of entrepreneurship. However, they differ in the nature of entrepreneurship (Westhead, 1988). New knowledge-intensive companies are established more often in cities (Andersson *et al.*, 2016) and rural areas (except agriculture), companies from the trade and automotive, industrial processing, and construction sectors are established the most often (Szmit *et al.*, 2017). The reasons for setting up businesses in rural and urban areas are also different. In the case of the former, they go beyond economic benefits and include lifestyle (Hollick & Braun, 2005), culture (Hustedde, 2007), social improvement (Dees, 1998), and the opportunity to build something (Sarasvathy, 2006). In rural areas, informal networks are much more important (Bosworth & Atterton, 2012; Escandón-Barbosa *et al.*, 2019). Simeoni and Testa (2018) explore and explain the so-called unconventional entrepreneurship precisely through the prism of its relationship with the type of commune, and the processes of setting up companies in rural areas are associated with social factors (Granovetter, 1985). The role of institutions in supporting entrepreneurship in rural and urban areas is also different (Vesala & Vesala, 2010; Klofsten *et al.*, 2020), which also refers to the effectiveness of incentives for starting new businesses (Naldi *et al.*, 2020). Thus far, the research findings allow for the formulation of the following hypothesis:

H1: The dynamics of the number of newly established enterprises in Poland is significantly dependent on the generic category of communes.

The second section will focus on the relationship between the type of commune and support instruments used and their effects on the creation of new companies. Inglot-Brzęk and Skica (2017) indicate that infrastructural (hard) instruments are appropriate for rural communes, while soft instruments (promotion, information, and planning) work better in urban and urban-rural communes. Budget instruments in relation to cities are studied by Poniatowicz and Wyszkowska (2014) who prove that the scope of local fiscalism (*e.g.* the space for applying tax instruments) increases with the size and wealth of the commune. Off-budget (soft) forms of support are analyzed by Chomiak-Orsa and Flieger (2012), showing their diversity, unequal effectiveness, and the need to adapt to the specificity (also type) of communes. Mickiewicz *et al.* (2021) prove that the effectiveness of forms of support is conditioned by the type of supported economic activity. Commercial activity is effectively supported by advisory instruments, services related to hospitality (financial instruments and attracting external investors), the construction and processing industry (stimulating social self-organisation), and modern services creating conditions for locating investments from outside the commune. Although the authors emphasize the importance of non-financial ('soft') instruments, Young and Kaczmarek (2000) showed that they are still poorly developed in Poland. These weaknesses are mainly visible in voivodship cities and municipal communes. Satoła (2014) supports this narrative and points directly to the ineffectiveness of tax instruments. Fazlagic *et al.* (2021) and Mickiewicz *et al.* (2021) checked the effectiveness of municipalities in supporting various forms of entrepreneurship but only in cities. They estimate the costs of these policies and emphasize the need for a separate approach (compared to other municipalities) to support the creation of new businesses in urban areas. This is confirmed by Naldi *et al.* (2020) on a sample of small and medium-sized cities. Brooks *et al.* (2019) went a step further and examined the role of public policy in creating entrepreneurial ecosystems in Polish cities. Their results show that these attempts were only partially successful, as entrepreneurship ecosystems have not yet been established in their areas. The presented research results allow us to conclude that the knowledge on the relationships between the type of commune and the instruments appropriate for it and the impact of the type of commune on the effectiveness of the instruments used needs to be deepened. Therefore, based on the literature review, two complementary hypotheses were formulated:

H2: The type of commune determines the use of instruments supporting entrepreneurship included in individual areas of supporting entrepreneurship.

H3: The type of commune affects the effectiveness of individual groups of instruments supporting entrepreneurship.

RESEARCH METHODOLOGY

The research was carried out between June and October 2019. The selection of local government units (LGUs) for the research sample was two-stage, in the first stage purposive sampling was used, accepting 735 communes participating in the Polish edition of the Global Entrepreneurship Monitor research project in 2015. In the second stage, dependent sampling was used, selecting 347 communes from the database of all communes in Poland in such a way as to provide the sample with the same structure as the actual structure of communes in Poland by type. The communes were surveyed using the CAWI/CATI method. The CATI method supplement the CAWI method in the case of all communes from the pool of 735 that did not return correctly completed questionnaires (352 communes in total), it was also the basic tool for examining the randomly selected communes (347 communes).

The assessment of activities introduced by communes in the field of local entrepreneurship development was carried out in four areas:

1. Cooperation between the commune and entrepreneurs (26 questions in the survey concerning a specific tool used by a given commune in this area).
2. Finance, taxes, and administration (22 questions).
3. Attracting investors and external funds by the commune (28 questions).

4. Supporting non-governmental organizations (eight questions). The list of questions concerning individual areas of cooperation between the commune and entrepreneurs and the numbering assigned to the individual instruments questions is presented in Appendix No. 1. Since these questions were dichotomous, the answers obtained on their basis were recoded to binary form in accordance with the principle: if the surveyed commune answered that it does not use the tool described in a given question in its activity, the variable describing this question received value '0,' while if it indicated that a given tool is used to support entrepreneurship in a given commune, the variable received value '1.'

We determined the impact of individual activities on the growth of newly established companies performed by municipalities using the GRG non-linear algorithm.

$$z_j = \sum_{i=1}^{m} \omega_i \cdot x_{ij} \tag{1}$$

In which:

m - is the number of tools included in a given area of supporting entrepreneurship by the j commune (number of questions in the survey related to a given area of supporting entrepreneurship);

x_i - is a dummy variable, the value of which depends on whether the given tool uses the i-th tool in its activity (whether the answer to a specific question was 'YES' or 'NO');

ω_i - is a weight defining the importance of the i-th tool in terms of supporting the development of entrepreneurship.

The procedure for estimating the values of the weights ω_i was as follows:

1. Surveyed communes were sorted in terms of entrepreneurship development, from the commune with the highest increase in the number of newly established enterprises in 2020 compared to 2011 (per 1000 inhabitants) to the commune with the largest decrease in this matter.
2. Taking into account the survey results based on the formula (1), the value of the synthetic variable z_j was determined for each commune, evaluating the commune's degree of involvement in the promotion of entrepreneurship in its area in each of the discussed j areas. It was initially assumed that each of the tools included in a given area of supporting entrepreneurship by a commune has the same meaning (the value of all weights $\omega_i = 1/m$).
3. On the basis of the obtained values of variable z_j, the communes were sorted in terms of supporting local entrepreneurship, from the commune with the highest z_j value to the commune with the lowest z_j value.
4. Using the tau-Kendall coefficient (Abdi, 2007), an assessment was made of the compatibility of the ordering of communes in terms of the development of entrepreneurship and in terms of supporting local entrepreneurship.
5. Using the GRG non-linear algorithm, the ω_i weights were modified in such a way that the obtained values of the z_i variable enabled the ordering of communes in terms of supporting entrepreneurship in a way that ensured obtaining the maximum value of the tau-Kendall coefficient. It was assumed that the weight values obtained on this basis meet two basic assumptions related to the weights of diagnostic variables, namely positivity $(w_i > 0)$ and summability to unity $\left(\sum_{i=1}^{m} w_j = 1\right)$.

As a result of the applied procedure, such values of ω_i weights were finally obtained, which ensured the greatest degree of linking the tools used by communes to support local entrepreneurship with the actual change of newly established enterprises in its area. This allowed for an objective assessment of the importance of activities undertaken by communes for the development of local entrepreneurship.

RESULTS AND DISCUSSION

Based on the preliminary Kruskal-Wallis test, it can be concluded that changes in the number of newly established enterprises in communes in Poland significantly depend on the type of commune. How-

ever, a deeper analysis of the numerical characteristics describing the formation of the discussed phenomenon in particular types of communes (Table 1) shows that only rural communes differ significantly from other communes. Practically only in this group of communes, both on the basis of the arithmetic mean and the median, an increase in the number of newly established economic entities per 1000 inhabitants could be observed. Comparing 2020 and 2011 data, in the remaining groups of communes, this indicator practically deteriorated affecting urban communes the most.

Table 1. Numerical characteristics of changes in the number of newly established enterprises per 1000 inhabitants in individual groups of communes in Poland in 2011-2020

Type of commune	N	Mean	Median	Min	Max	1. quartile	3. quartile	St. dev
Rural commune	476	20.84%	10.61%	-63.82%	337.77%	-6.26%	35.08%	44.56%
Urban commune	113	-6.42%	-11.39%	-38.89%	75.08%	-18.53%	1.82%	20.16%
Urban-rural commune	195	0.32%	-3.18%	-47.82%	73.51%	-12.79%	10.63%	19.63%
City with powiat rights	15	-4.84%	-8.41%	-26.20%	22.28%	-14.06%	2.36%	11.77%

Source: own elaboration.

Taking into account the diversified nature of the above-mentioned changes, the procedure of weighing the tools included in individual areas of supporting entrepreneurship in communes was carried out separately for each type of commune. This allowed us to additionally indicate possible differences in the 'importance' of these tools between particular groups of communes.

In the area of cooperation between communes and entrepreneurs, regardless of the type of commune, it was of no importance whether there were chambers of commerce or their branches in the commune (C3.1) and features of various crafts (C3.3). In the case of rural communes, this factor had a significant impact on the development of entrepreneurship in their area (tau-Kendalla=0.0749, p-value=0.0145), and the most important was whether the communes participated in the establishment of a loan fund (ω=0.2046), a technology park (ω=0.1977), and the investor service centre (ω=0.1795). Apart from the two previously mentioned tools, the following elements did not affect the development of entrepreneurship among rural communes: informing the commune about available sources of financing through brochures available in offices (C1.2), at meetings organized for this purpose (C1.3) and training (C1.4), organization of training by the commune on starting and running a business (C2), functioning of employers' organizations (C3.4), regional and local development agencies (C3.5), and technology parks (C3.7). In the case of urban communes (tau-Kendalla=0.0496, p-value=0.4361), the most important in the development of entrepreneurship was the establishment of a business incubator (ω=0.1331), participation in the process of creating strategic documents of entrepreneurs from the commune (ω=0.1302), investments in the public-private partnership formula (ω=0.1216), establishing a loan fund (ω=0.1171), or operating a regional or local development agency in the commune (ω=0.1105). In the case of urban-rural communes (tau-Kendalla=0.0814, p-value=0.0920), the five most important tools for supporting entrepreneurship in the area of cooperation with entrepreneurs were: location in the commune of a service point for entrepreneurs offering legal, financial and accounting advice, etc. (ω= 0.1259), participation of the commune in the establishment of a loan fund (ω=0.1259) and an information centre for business (ω=0.1246), organization of meetings by the commune informing about available sources of financing activities (ω=0.1230) and operation of industrial parks, technology parks in the commune business incubators, etc. (ω=0.1130). Among the cities with powiat rights, five most important tools for supporting entrepreneurship in the area of cooperation with entrepreneurs were (tau-Kendalla=0.2571, p-value=0.1815), the meetings organized by the commune informing about the available possibilities of co-financing activities (ω=0.1333) and brochures available in offices in this regard (ω= 0.1325), the functioning of incubators, technology and industrial parks in the commune (ω=0.1325), as well as the establishment of a credit guarantee fund (ω=0.1257) and a loan fund (ω=0.1025).

Detailed information on the shaping of the weights of individual tools included in the area of cooperation between the commune and entrepreneurs is presented in Table 2.

Table 2. Values of weights for tools supporting entrepreneurship in particular types of communes

Type of commune	C1.1	C1.2	C1.3	C1.4	C2	C3.1	C3.2	C3.3	C3.4	C3.5	C3.6	C3.7	C4	
Rural	0.0474	0	0	0	0	0	0.1284	0	0	0	0.1614	0	0	
Urban	0.0031	0	0	0	0	0	0	0	0	0.1105	0	0	0.0473	
Urban-rural	0.0957	0	0.1230	0	0.0305	0	0.0888	0	0	0	0.0108	0.1130	0.1259	
City with powiat rights	0	0.1325	0.1333	0.0207	0	0	0	0	0.0877	0.0175	0.0292	0.1325	0	
Type of commune	**C5**	**C6**	**C7**	**C8.1**	**C8.2**	**C8.3**	**C8.4**	**C8.5**	**C8.6**	**C8.7**	**C8.8**	**C8.9**	**C8.10**	
Rural	0	0.0500	0	0.0066	0.0140	0.1795	0	0.204599	0	0.0079	0.1978	0	0.0024	
Urban	0.0963	0.1216	0.1302	0.0786	0.1331	0.1015	0.0485	0.1171	0.0006	0	0.0034	0.0082	0	
Urban-rural	0	0.0004	0.0405	0.0002	0.0720	0	0	0.1259	0	0.0488	0	0.1246	0	
City with powiat rights	0.0975	0.0998	0	0	0	0	0	0.1025	0.0212	0	0	0	0.1257	
Type of commune	**D1**	**D.2.1**	**D.2.2**	**D3**	**D4**	**D5.1**	**D5.2**	**D5.3**	**D5.4**	**D5.5**	**D5.6**			
Rural	0.1806	0	0.0884	0.0833	0.0562	0.1804	0	0	0	0	0			
Urban	0.1393	0.0602	0.0245	0.0027	0	0.0146	0.0916	0.1382	0	0	0.1114			
Urban-rural	0	0	0	0.1399	0	0	0.0680	0	0	0	0.1332			
City with powiat rights	0.1060	0	0.1073	0.0000	0.0942	0.0957	0.1041	0	0.1051	0	0.0950			
Type of commune	**D5.7**	**D5.8**	**D5.9**	**D5.10**	**D5.11**	**D6**	**D7.1**	**D7.2**	**D7.3**	**D7.4**	**D7.5**			
Rural	0	0.1276	0.0001	0	0.1665	0.0008	0	0.1161	0	0	0.0000			
Urban	0.0146	0.1318	0.1084	0	0.0000	0	0.0025	0.0051	0.1355	0	0.0194			
Urban-rural	0.1258	0	0.0114	0	0.0229	0	0.0704	0.0674	0.0960	0.1302	0.1348			
City with powiat rights	0	0	0	0	0.0990	0.0872	0.0713	0.0352	0.0000	0	0			
Type of commune	**E.1.1**	**E.1.2**	**E.1.3**	**E.1.4**	**E.1.5**	**E.1.6**	**E.1.7**	**E.1.8**	**E.1.9**	**E.1.10**	**E2**	**E4.1**	**E4.2**	**E4.3**
Rural	0	0.0616	0.0605	0.0309	0.1204	0	0.0002	0.0262	0.0449	0.1306	0.0023	0.0300	0	0
Urban	0.0805	0.0183	0	0	0.1217	0	0.1236	0.0391	0.0032	0	0.1281	0	0.1218	0
Urban-rural	0.1168	0.1235	0	0.0351	0.1266	0	0	0	0	0	0	0.1001	0	0
City with powiat rights	0.0774	0.0784	0.1130	0.1122	0	0.0819	0.0761	0.1122	0.0536	0	0.0547	0	0.0425	0
Type of commune	**E4.4**	**E4.5**	**E4.6**	**E4.7**	**E5.1**	**E5.2**	**E5.3**	**E5.4**	**E5.5**	**E6.1**	**E6.2**	**E6.3**	**E6.4**	**E6.5**
Rural	0	0.0171	0	0.1297	0.1262	0	0	0	0.0124	0.0975	0	0	0	0.1097
Urban	0	0.0062	0.0022	0	0	0.0090	0.1023	0.0035	0.0061	0.1310	0.0098	0.0357	0.0074	0.0505
Urban-rural	0.0396	0.0080	0.1222	0	0	0.0090	0.0496	0	0.0261	0.0837	0	0.1076	0.0496	0.0027
City with powiat rights	0.0283	0.0654	0	0	0.0059	0	0.0608	0	0.0012	0.0365	0	0	0	0
Type of commune	**F1.1**	**F1.2**	**F1.3**	**F1.4**	**F1.5**	**F1.6**	**F1.7**	**F1.8**						
Rural	0.1923	0.1923	0.0831	0.1879	0	0.1537	0.1906	0						
Urban	0	0	0.1801	0.2283	0.2280	0.1696	0.1941	0						
Urban-rural	0.2438	0.1508	0.0042	0.1820	0.2153	0.0058	0.1981	0						
City with powiat rights	0	0.2291	0.0703	0.1320	0.0712	0.0689	0.2244	0.2042						

Source: own calculation.

The obtained variables z_i describing the scales of the tools used in individual areas also enable the assessment of the degree of impact of individual areas of communes' activity on supporting local entrepreneurship. On the basis of the estimated weights determining the link between individual areas and the rate of increase in the number of newly established enterprises in communes, it can be concluded that in the case of rural communes, almost 50% of the importance in the development of local entrepreneurship were tools describing the cooperation of the commune with entrepreneurs. In the case of urban communes, activities in the area of attracting investors and funds from outside were of the greatest importance (62%), in urban-rural communes almost 40% of small tools included in the area of finance, taxes and administration, while in cities with powiat rights, activities in the area of finance, taxes and administration, attracting investors and funds from outside, supporting non-governmental organizations were practically of the same importance. At the same time, in the case of rural communes, actions taken in the field of supporting non-governmental organizations were of no importance in this regard, and in the case of rural communes, actions in the area of cooperation with entrepreneurs were of no importance (Table 3).

Table 3. Values of weights for individual areas of communes' activity in the field of supporting local entrepreneurship

Type of commune	Area of cooperation between the commune and entrepreneurs	Area of finance, taxes and administration	Area of attracting investors and funds from outside	Area of supporting non-governmental organizations
Rural	0.4859	0.2325	0.2815	0.0000
Urban	0.0000	0.2032	0.6177	0.1790
Urban-rural	0.3054	0.3880	0.2792	0.0274
City with powiat rights	0.1141	0.3101	0.2813	0.2944

Source: own elaboration.

Taking into account the importance of individual areas and the importance of tools used by their governments, among all the previously indicated 84 tools, in the case of rural communes the most important activities in terms of stimulating local entrepreneurship was whether the commune participated in the establishment of an entrepreneurship support centre (9.94%), provided information for business (9.61%), established local development agencies (8.72%), and whether there are associations and foundations supporting entrepreneurship (7.84%) or craft chambers (6.24%) in the commune. In the case of urban communes, such activities included promoting investment values via the website or public information bulletin (8.09%), operating a special economic zone (791%), providing a website in a foreign language (7.64%), disseminating information on financing activities (7.53%), and providing individual service when registering business activity (7.52%). In urban-rural communes, the most important were the granting of tax reliefs by the commune to new private entrepreneurs (5.43%), conducting an appropriate policy of sale (perpetual usufruct) or exchanging commune real estate in the process of supporting entrepreneurship (5.23%), providing financial support by the commune in the form of sureties and guarantees (5.17%), and developing detailed rules for using commune property in the process of supporting entrepreneurship (5.05%). In cities with powiat rights, tools that are part of supporting non-governmental organizations were of particular importance, including informing such organizations about sources of extra-budgetary funds (5.23%), taking such organizations under the patronage of the commune (5.21%), or appointing a responsible person in the office for contacts with non-governmental organizations (4.73%). Detailed information on the final shaping of the weights of individual tools is presented in Table 4 (Annex 2).

CONCLUSIONS

Based on research conducted, the first hypothesis that the type of commune affects the increase in the number of newly established enterprises turned out to be true, which was confirmed by the Kruskal-Wallis test analysis. However, after deepening the inquiry, it was concluded that the number of newly established enterprises increased only in rural communes. This could be due to the fact that in these specific types of communes, the saturation with enterprises was the lowest, hence, they were somehow

catching up with other types of municipalities, where these indicators decreased in the analyzed period. A possible explanation for the increase in the number of new entities in villages compared to cities may be the relocation of the seats of already existing enterprises from cities to villages (especially those located near the cities) caused, for example, by lower fees and taxes applied in rural communes. Hypothesis 2 turned out to be true. The analysis of the importance of activities carried out by communes in the development of local entrepreneurship, broken down by support areas, showed that communes used various instruments. This is in line with the research of Brzozowska *et al.* (2018) who believe that the policy of economic, institutional, and infrastructural incentives dedicated to economic entities is feasible through enterprise support instruments used by communes. This issue was also analysed by, among others, Mickiewicz *et al.* (2016). The phenomenon of instrumentalization of entrepreneurship support in Poland, Estonia, and Slovakia is described in more detail in the book (Skica & Rodzinka, 2020).

Our research also showed, which is consistent with (Skica & Rodzinka, 2021 after Prange, 2008; Porter & Stern, 2001), that it is impossible to indicate one instrument in any of the areas that would be of great importance in all types of communes. Therefore, governors managing different types of communes should choose a different set of instruments to support entrepreneurship. A different set of instruments should be used in rural communes, another in urban communes, and yet another in urban-rural communes. The exact list of the most effective tools depending on the type of commune is indicated in the results part.

The third hypothesis also turned out to be true: the type of commune is important in the context of the effectiveness of individual groups of instruments supporting entrepreneurship. In the case of urban-rural communes and cities with powiat rights, instruments in the area of finance turned out to be the most effective, while for rural communes instruments in the area of cooperation with entrepreneurs were important. In the case of urban communes, attracting investors and funds from outside had the greatest impact.

Somewhat surprising were the results of research on the poor growth of start-ups in urban areas. However, given a deeper analysis, slower growth in cities than outside them may indicate the convergence effect. In communes with a high saturation of economic activity, this increase is lower, and in communes with a lower number of operating entities, new registrations grow faster. In addition, different types of communes determine the effectiveness of different instruments. According to the analysis, these instruments are not distributed randomly. Various instruments correspond to the different potential of supporting entrepreneurship in communes (*e.g.* rural and urban). For example, the importance of a technology park will not work in most rural communes, where the technological infrastructure is at a lower level than in urbanized communes. Similarly, with a good base for entrepreneurship in urban-rural communes, counselling turns out to be crucial. The results of our research confirm the previous data presented by the Supreme Audit Office (NIK, 2018).

A thorough analysis of the research results allows to determine which tools give better results and which do not bring the desired ones. Based on the obtained results, the authorities of communes can shape the policy of support for the development of entrepreneurship. This seems to be justified, because despite the fact that many authors have tried to advise practitioners on the effectiveness of the tools used to support entrepreneurship, such as the already quoted Olsson *et al.* (2020), Audretsch *et al.* (2015), and Brooks *et al.* (2019), none of the authors presented the situation in such a comprehensive way. None gave such an unambiguous and accurate answer on the effectiveness of using so many instruments supporting entrepreneurship.

However, our research has its limitations. The biggest of them concerns the fact that only Polish communes were surveyed, so the results of the research can be directly applied only among communes in this country. Differences between countries and the organization of local government systems largely limit the possibility of applying the solutions postulated in the study to communes operating in other countries. Some instruments may even be inapplicable elsewhere because they are unavailable. Nevertheless, the cognitive value of the research is undeniable, and its implementation in other systems is possible after making the necessary adjustments.

The results of the study proved that there is no one universal area or instrument that would guarantee with high probability success in the form of an increase in the level of entrepreneurship in a

commune, regardless of its type. It was shown that in specific types of communes, it is possible to identify tools that are more effective than others.

Nevertheless, each entity has its own specific conditions, which make some tools more effective than others.

The conclusions of this study show that the impact of soft measures taken by communes on the level of entrepreneurship is negligible. Therefore, in the next stages of the study, it is possible to focus on the remaining local conditions that may determine these values. Infrastructure investments seem to be an important direction, so the next stage of the work will undertake the analysis, scope, extent, and effects of infrastructure investments and their impact on the level of local entrepreneurship.

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Appendix A: Groups of tools describing the cooperation of the commune with entrepreneurs and questions numbering

Group describing the cooperation of the commune with entrepreneurs
Among the tools describing the cooperation of the commune with entrepreneurs, the subject of the study was whether:
1. the commune informs residents and entrepreneurs about the available funding opportunities:
   a. on the website of the municipality (C1.1);
   b. through brochures available at the office / through advertisements in the mass media (C1.2);
   c. at meetings organized for this purpose with stakeholders (C1.3);
   d. by organizing or supporting training on how to apply for such funds (C1.4);
2. the commune is involved in the organization of trainings preparing to take up and run a business (C2);
3. in the area of the commune, there are:
   a. chambers of commerce or their branches (C3.1);
   b. chambers of crafts (C3.2);
   c. characteristics of various crafts (C3.3);
   d. employers' organizations (C3.4);
   e. regional or local development agencies (C3.5);
   f. associations or foundations supporting entrepreneurs (C3.6);
   g. industrial and technological parks, business incubators (C3.7)
4. business service points offering legal, financial, and accounting advice, etc. are located in the commune (C4);
5. municipal services in the commune are provided by private companies (C5);
6. the commune has implemented or is implementing investments in the form of a public-private partnership (C6);
7. entrepreneurs from the commune participated in the process of creating strategic documents (C7);
8. the commune participated in the establishment of:
   a. credit guarantee fund (C8.1);
   b. business incubator (C8.2);
   c. investor service centre (C8.3);
   d. local development agencies (C8.4);
   e. loan fund (C8.5);
   f. business support centre (C8.6);
   g. industrial park (C8.7);
   h. technology park (C8.8);
   i. business information centre (C8.9);
   j. an association or foundation supporting entrepreneurs (C8.10).

Group describing the area of finance, taxes, and administration
The second group of tools describing the support of local entrepreneurship by communes were tools included in the area of finance, taxes, and administration. In this area, the subject of the analysis was whether the commune:
1. is involved in financial support for entrepreneurs (guarantees, guarantees, loans) (D1);
2. introduces facilitations for enterprises conducting business activity through:
   a. preferential rates of tax on means of transport (D2.1);
   b. preferential property tax rates (D2.2);
   c. grants tax relief to new private companies (D3);
   d. shares/sells the municipal property to private companies (D4);
3. uses economic and financial tools such as:
   a. preferential (lower than maximum) tax rates (D5.1);
   b. tax credits for entrepreneurs (D5.2);
   c. tax exemptions for entrepreneurs (D5.3);
   d. write-off of tax arrears (D5.4);
   e. payment of tax or tax arrears in instalments (D5.5);
   f. tax deferral (D5.6);
   g. preferences in determining the fees paid by entrepreneurs to the commune budget (D5.7);
   h. financial support in the form of sureties and guarantees (D5.8);
   i. financial support in the form of loans (D5.9);
   j. actions assuming the inclusion of investment areas in the SEZ (D5.10);
   k. price policy instruments related to utilities (D5.11);

4. analyzes the financial consequences for the budget of the entrepreneurship support policy (D6);
5. in the process of supporting entrepreneurship, it uses such tools of the commune's property management policy as:
    a. fees for the use of land, facilities and equipment owned by the commune (D7.1);
    b. pricing systems for the use of land and facilities owned by the municipality (D7.2);
    c. benefit payments (D7.3);
    d. detailed rules for the use of municipal property (D7.4);
    e. sale (perpetual usufruct) and exchange of municipal property (D7.5).

Group describing the area of acquiring investors and funds from outside by the commune

The analysed group of factors were tools in the area of attracting investors and funds from outside by the commune. In this group, the subject of the analysis was whether:

1. the commune conducts activities aimed at attracting new investors through:
    a. marketing activities, advertising the commune outside (E1.1);
    b. assistance in finding vacant land or premises (E1.2);
    c. assistance in the recruitment and training of employees (E1.3);
    d. advice, including legal and financial (E1.4);
    e. individual service when registering business activity (E1.5);
    f. websites (E1.6);
    g. websites in a foreign language (E1.7);
    h. information and promotion materials in a foreign language (E1.8);
    i. promoting the commune's offer at foreign fairs (E1.9);
    j. separation of an organizational unit or position for servicing foreign investors (E1.10);
2. there is a special economic zone (E.2) in the commune;
3. as part of cooperation with entrepreneurs, the commune uses:
    a. advice and consultation (E4.1);
    b. dissemination of information on financing activities (E4.2);
    c. dissemination of information necessary to run a business (E4.3);
    d. assistance in setting up business associations (E4.4);
    e. support in staff recruitment (E4.5);
    f. support in staff training (E4.6);
    g. promotion and dissemination of good practices (E4.7);
4. the form of advice provided to entrepreneurs in the field of running a business was:
    a. electronic guide published on the website of the office (E5.1);
    b. organization of thematic training (E5.2);
    c. running a permanent point of advice and service for entrepreneurs (E5.3);
    d. meetings or fairs involving, inter alia, NGOs (E5.4);
    e. guide or information materials in paper version (E5.5);
5. the form of promotion of the commune's investment values carried out by local government authorities is:
    a. website of the commune or public information bulletin (BIP) (E6.1);
    b. publications on the commune (brochures, albums, advertising folders) (E6.2);
    c. participation in rankings and competitions organized for municipalities (E6.3);
    d. participation in fairs and exhibitions (E6.4);
    e. running a consultation/information point (E6.5).

A group describing the area of supporting non-governmental organizations

The last, fourth group of researched tools were the activities of municipalities in the field of supporting non-governmental organizations. In this area, the subject of interest was whether:

1. municipal offices supported such organizations by:
    a. free access to premises for statutory activities (F1.1);
    b. provision of materials and equipment (F1.2);
    c. informing non-governmental organizations about the sources of obtaining extra-budgetary funds (F1.3);
    d. promoting non-governmental entities operating in the field of public benefit (F1.4);
    e. helping NGOs to establish national and international contacts (F1.5);
    f. assisting in the establishment of NGOs (F1.6);
    g. designation of a person in the office responsible for contacts with non-governmental organizations (F1.7);
    h. patronage over the activities of non-governmental organizations (F1.8).

Appendix B:

Table 4. Values of weights for individual tools used by communes in the process of supporting entrepreneurship

TOOLS	Rural	Urban	Urban-rural	City with powiat rights
C1.1	0.0230	0.0000	0.0292	0.0000
C1.2	0.0000	0.0000	0.0000	0.0151
C1.3	0.0000	0.0000	0.0376	0.0152
C1.4	0.0000	0.0000	0.0000	0.0024
C2	0.0000	0.0000	0.0093	0.0000
C3.1	0.0000	0.0000	0.0000	0.0000
C3.2	0.0624	0.0000	0.0271	0.0000
C3.3	0.0000	0.0000	0.0000	0.0000
C3.4	0.0000	0.0000	0.0000	0.0100
C3.5	0.0000	0.0000	0.0000	0.0020
C3.6	0.0784	0.0000	0.0033	0.0033
C3.7	0.0000	0.0000	0.0345	0.0151
C4	0.0000	0.0000	0.0384	0.0000
C5	0.0000	0.0000	0.0000	0.0111
C6	0.0243	0.0000	0.0001	0.0114
C7	0.0000	0.0000	0.0124	0.0000
C8.1	0.0032	0.0000	0.0000	0.0000
C8.2	0.0011	0.0000	0.0000	0.0143
C8.3	0.0068	0.0000	0.0220	0.0000
C8.4	0.0872	0.0000	0.0000	0.0000
C8.5	0.0000	0.0000	0.0000	0.0000
C8.6	0.0994	0.0000	0.0384	0.0117
C8.7	0.0000	0.0000	0.0000	0.0024
C8.8	0.0038	0.0000	0.0149	0.0000
C8.9	0.0961	0.0000	0.0000	0.0000
C8.10	0.0000	0.0000	0.0381	0.0000
D1	0.0420	0.0283	0.0000	0.0329
D.2.1	0.0000	0.0122	0.0000	0.0000
D.2.2	0.0206	0.0050	0.0000	0.0333
D3	0.0194	0.0006	0.0543	0.0000
D4	0.0131	0.0000	0.0000	0.0292
D5.1	0.0420	0.0030	0.0000	0.0297
D5.2	0.0000	0.0000	0.0000	0.0000
D5.3	0.0387	0.0000	0.0089	0.0307
D5.4	0.0000	0.0186	0.0264	0.0323
D5.5	0.0000	0.0281	0.0000	0.0000
D5.6	0.0000	0.0000	0.0000	0.0326
D5.7	0.0000	0.0000	0.0000	0.0000
D5.8	0.0000	0.0226	0.0517	0.0295
D5.9	0.0000	0.0030	0.0488	0.0000
D5.10	0.0297	0.0268	0.0000	0.0000
D5.11	0.0000	0.0220	0.0044	0.0000
D6	0.0002	0.0000	0.0000	0.0270
D7.1	0.0000	0.0005	0.0273	0.0221
D7.2	0.0270	0.0010	0.0261	0.0109
D7.3	0.0000	0.0275	0.0373	0.0000
D7.4	0.0000	0.0000	0.0505	0.0000
D7.5	0.0000	0.0039	0.0523	0.0000
E.1.1	0.0000	0.0497	0.0326	0.0218

TOOLS	Rural	Urban	Urban-rural	City with powiat rights
E.1.2	0.0173	0.0113	0.0345	0.0221
E.1.3	0.0170	0.0000	0.0000	0.0318
E.1.4	0.0087	0.0000	0.0098	0.0316
E.1.5	0.0339	0.0752	0.0353	0.0000
E.1.6	0.0000	0.0000	0.0000	0.0230
E.1.7	0.0000	0.0764	0.0000	0.0214
E.1.8	0.0074	0.0241	0.0000	0.0316
E.1.9	0.0126	0.0020	0.0000	0.0151
E.1.10	0.0368	0.0000	0.0000	0.0000
E2	0.0006	0.0791	0.0000	0.0154
E4.1	0.0084	0.0000	0.0279	0.0000
E4.2	0.0000	0.0753	0.0000	0.0120
E4.3	0.0000	0.0000	0.0000	0.0000
E4.4	0.0000	0.0000	0.0110	0.0079
E4.5	0.0048	0.0038	0.0022	0.0184
E4.6	0.0000	0.0013	0.0341	0.0000
E4.7	0.0365	0.0000	0.0000	0.0000
E5.1	0.0355	0.0000	0.0000	0.0017
E5.2	0.0000	0.0056	0.0025	0.0000
E5.3	0.0000	0.0632	0.0138	0.0171
E5.4	0.0000	0.0021	0.0000	0.0000
E5.5	0.0035	0.0038	0.0073	0.0003
E6.1	0.0275	0.0809	0.0234	0.0103
E6.2	0.0000	0.0061	0.0000	0.0000
E6.3	0.0000	0.0221	0.0300	0.0000
E6.4	0.0000	0.0046	0.0138	0.0000
E6.5	0.0309	0.0312	0.0007	0.0000
F1.1	0.0000	0.0000	0.0067	0.0000
F1.2	0.0000	0.0000	0.0041	0.0321
F1.3	0.0000	0.0322	0.0001	0.0532
F1.4	0.0000	0.0409	0.0050	0.0398
F1.5	0.0000	0.0408	0.0059	0.0297
F1.6	0.0000	0.0304	0.0002	0.0402
F1.7	0.0000	0.0348	0.0054	0.0473
F1.8	0.0000	0.0000	0.0000	0.0521

Note: For an explanation of the symbols, see Appendix A.
Source: own elaboration.

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Conflict of Interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Using trigonometric seasonal models in forecasting the size of withdrawals from automated teller machines

Henryk Gurgul, Łukasz Lach, Marcin Suder, Karol Szpyt

A B S T R A C T
Objective: The study focused on verifying the impact of the calendar and seasonal effects on the accuracy of forecasts of cash withdrawals from automated teller machines (ATMs). In this article, we investigated a possible use of the so-called trigonometric seasonality, the Box-Cox transformation, ARMA errors, trend, and seasonal components (TBATS) models to forecast withdrawals from ATMs. In practice, the SARIMA model is widely used as a forecasting tool. However, the major limitation of SARIMA models is that it allows just one single seasonality pattern to be taken into account, e.g., weekly seasonality. At the same time, cash withdrawals from ATMs display overlapping multi-seasonality. Therefore, the goal of this article is to compare the SARIMA model with the TBATS model, both in basic forms and forms extended with event-specific dummies.
Research Design & Methods: Empirical research was conducted by means of fitting SARIMA and TBATS models to daily time series of withdrawals from 74 ATMs managed by one of the largest ATM operators in Poland. The dataset covered the period of 2017-2019.
Findings: Forecasting levels of cash withdrawals plays a crucial role in the management of ATM networks, both in the case of a single ATM as well as the whole network. Prediction accuracy has a direct impact on the operational costs of the network. These costs result from activities such as freezing cash in an ATM, preparing it, and transporting it to an ATM. Therefore, the choice of a proper forecast model is of special importance. According to statistical evidence in our study, the basic TBATS model gives more accurate forecasts than the basic SARIMA model widely used in practice.
Implications & Recommendations: The multi-seasonality of ATM withdrawals means that it is necessary to use techniques that take such phenomena into account in a single joint model. Multi-seasonality can be modelled using TBATS models. The study confirmed that TBATS models can be considered useful alternatives in planning cash replenishments in ATM networks.
Contribution & Value Added: This article is an extensive empirical study on the selection of proper methods and forecasting models necessary to predict withdrawals from ATMs with overlapping multi-seasonalities and calendar effects. We proved that taking seasonal and calendar effects into account when forecasting withdrawals from ATMs significantly reduces forecast errors. Statistically significant improvement in forecast accuracy was observed both for SARIMA and TBATS. After taking calendar effects into account, TBATS forecast errors were slightly smaller than those resulting from corresponding SARIMA models. However, this result is statistically insignificant. The results of this study imply a need for further studies on the applications of TBATS models in forecasting the required cash level in ATMs, which in turn may help improve the efficiency of ATMs network management.

Article type:	research article
Keywords:	ATM; withdrawals; forecasts of withdrawals; ATM network management; TBATS model; SARIMA model; calendar effects
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INTRODUCTION

Automated teller machines (ATMs) are computerized telecommunication devices. They provide the customers of financial institutions with a method of performing financial transactions in a public space without the need for a human clerk. Automated teller machines are part of a so-called 'cash supply chain,' 'cash chain,' or 'currency chain,' which generally consists of a Central Bank, mints/banknote printers, a distribution network, commercial banks, public customers, and businesses. A cash chain is characterized by the forward and backward motion of coins and notes to distribute cash to the public and ensure that the cash in circulation remains 'fit' (*i.e.*, valid for circulation). The return flow of cash serves the purpose of removing all unfit cash (especially notes) and returning it to the Central Bank. The cash chain can be classified as a closed-loop supply chain because, ideally, over time, no cash leaves circulation. Automated teller machines are supplied/replenished by the distribution network, while the public or business customers demand/withdraw cash. Of the wide variety of ATM types currently deployed globally, the classic ATM with the ability to dispense only banknotes is still the most widespread.

The most recent reports of the National Bank of Poland (NBP; see the report of NBP for the first quarter of 2022) stress that withdrawals are becoming fewer in number. However, the value of individual transactions is becoming larger. This tendency, which has been observed in recent years, is not profitable for the operators of ATM networks. This situation has two negative consequences. First of all, the growing value of individual withdrawals means that operators must use more cash to replenish ATMs. Therefore, the costs of frozen cash and transporting it are higher. Secondly, the reduced number of withdrawals is a source of lower income from *interchange* and from the advertisements that are displayed on the screen for customers while they are withdrawing cash from ATMs. If this tendency continues then the revenues of ATM operators will fall. In this situation, the operators of ATM networks must try to reduce the costs of servicing the networks. A substantial proportion of these costs results from transporting cash and freezing it.

The costs of cash management can be as high as 50% of the total service costs of ATMs (Simutis *et al.*, 2007; Toi, 2011; Suder, 2015). The greatest challenge faced by ATM operators is to minimize the charges resulting from their cash service. At the same time, the operator tries to ensure that there is always an appropriate amount of cash in ATMs. In other words, the goal is to keep at an acceptably low level the probability that the user of an ATM faces a lack of cash in the ATM.

Cash management goals can be achieved if cash supplies in ATMs are properly managed. The replenishment process depends on proper, accurate forecasts of cash withdrawals from ATMs. Therefore, ATM operators, supported by researchers, are trying to find better forecast methods that will ensure better forecast quality. Thus, one research direction consists in testing the new models with respect to their effectiveness in forecasting cash demand. Some classes of models that are well-known in other areas of applied econometrics have not been verified or even used in cash withdrawals from ATMs. In particular, many special calendar effects have not been included in the forecasting models used.

The most frequently used techniques in forecasting withdrawals from ATMs are based on SARIMA models. These models take seasonality (*e.g.,* weekly seasonality) into account but do not reflect multiseasonality in the same time interval (*e.g.,* daily, weekly, monthly, all in the same time interval). At the same time, cash withdrawals from ATMs display multi-seasonality. The overlapping seasonalities imply that when modelling withdrawals techniques that consider multi-seasonality in one model should be used. The multi-seasonality of processes is modelled in different fields of study by TBATS models but not in the ATM framework. Therefore, our task was to compare the forecasts of withdrawals by traditional SARIMA models to TBATS models (not used in modelling withdrawals from ATMs). Moreover, we verified the extent to which including seasonal and calendar effects improves forecast quality.

Our research was based on daily withdrawals from 74 ATMs managed by one of the largest ATMs networks in Poland. The data used encompassed the period between January 2017 and December 2019.

This article is divided into five sections. The next section will present the literature overview concerning the forecast of withdrawals from ATMs and the application of TBATS models in the forecasts

of selected time series. Based on the literature, in the final part of this section, we will state our research hypotheses. In section three, we will describe the data used in the article. In particular, we will define the seasonal and calendar effects included in the models and present the models used in this study. In section four, we will show the computations results. In the last part of the article, section five, we will present the conclusions and limitations of this research. Replication codes accompanying the article are available in the Appendix at the end of the article.

LITERATURE REVIEW AND HYPOTHESES DEVELOPMENT

Over the last two decades, ATMs have been one of the most important sources of cash. However, the literature concerning the functioning of ATMs, logistics, convoy of cash, and cash management in ATM networks is rather scarce. Currently, as of 2 October 2022, the Scopus database lists less than 1000 articles that mention all aspects of ATMs' operations. Most of these contributions (almost 80%) consider issues concerning ATMs construction, the service of ATMs, and their functioning as tele-informatic devices. Contributions on the time series of ATM withdrawals make up 12% of the total number of articles on ATMs. The low number of articles on withdrawals is caused to a large extent by a lack of respective data.

Articles concerning the management of ATM networks mostly present two basic questions. One concentrates on the econometric properties of the time series of withdrawals with a special focus on seasonal and calendar effects. The other issue most frequently considered is the selection of proper methods and forecasting models necessary to predict withdrawals from ATMs.

An interesting article on seasonal and calendar effects was written by Rodrigues and Esteves (2010), who considered their influence on withdrawals from ATMs in Portugal. They took the following calendar effects into account: the day of the week, the week of the month, the month of the year, and the effects of church and national holidays. Rodrigues and Esteves stress the significance of these effects with respect to daily withdrawals from ATMs. Their results show the impact of seasonal and calendar effects on the structure of the time series of withdrawals from ATMs. The authors used the quarterly national accounts' procedure of adjusting data for seasonality and working days effects. This procedure allowed them to apply the ATM series as an instrument for forecasting private consumption.

Findley and Monsell's results (2009) are mostly in line with those of Rodrigues and Esteves (2010). Findley and Monsell established the impact of not only seasonal effects (day of week, week of month, month of year) but also church and national holidays. They suggest that in modelling and forecasting the time series of withdrawals, it is necessary to consider the specific day and month. The authors used X-12-ARIMA (Census Bureau's seasonal adjustment program).

The time series of withdrawals are the subject of an article by Cabrero *et al.* (2009). Among other issues, they investigated the daily cash demand from ATMs. They suggest daily, monthly, and yearly patterns. Cabrero *et al.* (2009) indicated payment patterns and customers behaviour. They emphasize the effect of the trading day (an increase in banknotes directly before the weekend and a decrease after weekends). Similarly, the number of banknotes is lower in the first half of the month and higher at the end of the month. Moreover, the authors draw attention to the unavoidable impact of holidays on the demand for cash from ATMs. Cabrero *et al.* (2009) compared two competing approaches to model seasonality in daily time series: the ARIMA-based approach and the structural time series approach.

Simutis *et al.* (2008), Takala and Viren (2007), and Toit (2011) indicate that withdrawals from ATMs can be impacted by paydays in institutions and firms, holiday periods, and other factors that determine trends and weekly, monthly, and yearly cycles. These calendar effects are important within the framework of the logistics of ATM networks.

Calendar effects in the time series of withdrawals are analyzed in articles by Gurgul and Suder (2012, 2016), and Suder (2015). They investigate calendar and seasonal effects on the time series of the number and size of withdrawals from the ATMs of one of the largest network operators in Poland. The results of their analyses are in line with the previously mentioned analyses. The authors stress that calendar effects can be observed in the time series of ATM withdrawals (both the size of particular withdrawals and the number of withdrawals). However, the impact of particular effects depends on an ATM's location.

In the articles reviewed so far, the authors focus on detecting calendar and seasonal effects and conclude that they should be taken into account when predicting ATM withdrawals. However, there are also contributions which try to include calendar and seasonal effects in models that forecast cash replenishments.

Wagner (2010) detected seasonal and calendar effects not only in the time series of cash withdrawals from the analyzed ATMs but also included these effects in his prediction models. He used the SARIMA and VAR models. His goal was to predict the time series of withdrawals from ATMs which belong to one European bank. He concluded that modelling special days (*i.e.* days with calendar or seasonal effects in day or month) using dummies is better than forecasting without taking calendar or seasonal effects into account. Forecast errors in extended models are essentially lower.

Gurgul and Suder (2013) apply SARIMA models and switching models to the forecast of withdrawals from ATMs and Bielak *et al*. (2015) describe the results of forecasting withdrawals from ATMs in bank branches using the ARMAX model and neural networks.

According to Rafi *et al*. (2021), the changing demands of users and changing seasonal patterns are very challenging problems for an ATM network. Financial institutions must fill each ATM with the optimal amount of cash. In this study, the authors used a time series model similar to ARIMA. Furthermore, this study used ATM data from six different financial organizations in Pakistan. There were 2040 distinct ATMs and 18 months' worth of replenishment data from these ATMs. The mean absolute percentage error (MAPE) and symmetric mean absolute percentage error (SMAPE) were used to evaluate the models. The suggested model, based on ARIMA, turned out to be better than models based on neural networks (lower MAPE and SMAPE in the case of ARIMA).

The goal of Fallahtafti *et al*. (2022) was to forecast the ATM cash demand for the periods both before and during the Covid-19 pandemic. Their other aim was to compare several statistical (based on ARIMA) and machine learning models in terms of different algorithms and assumptions. To achieve this goal, the ATMs were first clustered based on accessibility and surrounding environmental factors. These factors significantly affect the cash withdrawal pattern. The authors found that during Covid-19 and in times of shocks in demand and huge volatility of withdrawals, the statistical models (ARIMA and SARIMA) can provide better forecasts. According to the authors, the probable reason for this is that such models perform well, especially for short-term predictions. This kind of model allows overfitting to be minimized.

A relatively large number of authors who write about forecasting ATM withdrawals use neural networks. Including calendar effects, they are creating neural networks and show that their method is better than autoregression models. Interesting empirical studies on the applications of neural networks have been conducted by Simutis *et al.* (2007; 2008) and Acuña *et al.* (2012). They attempt to optimize cash management by selecting an appropriate withdrawal prediction model. The authors demonstrate that the use of neural networks can reduce network service costs by as much as 20%.

More recent articles on the use of neural networks in forecasting withdrawals from ATMs are by Serengil and Ozpinar (2019), Ekinci *et al*. (2015), Zandevakili and Javanmard (2014), Bhandari and Gill (2016). The promising computer-supported methods with respect to ATM applications may be based on evolutionary algorithms which are thoroughly presented in Sieja and Wach (2019). They also indicate the possibility of their implementation for the needs of the economy, especially the entrepreneurial economy.

To the best of our knowledge, previous studies have not suggested how to model usage or forecast withdrawals from ATMs using TBATS. Notably, we checked the Scopus and Google Scholar databases on 2 October 2022. This result is surprising, because this class of model is widely used in forecasting time series. Moreover, the authors of these contributions demonstrate that forecasts obtained from TBATS models are often more accurate than the forecasts derived from SARIMA models or neural networks. We used the *nnetar* function available in R package *forecast*. Please note that numerical experiments with neural networks convinced us that for our data set, SARIMA models produce more accurate predictions than neural networks. As a consequence, we focused on the comparison between TBATS and SARIMA.

Important contributions to TBATS theory and applications, as well as packages (in the R environment), have been developed by De Livera *et al.* (2011). Moreover, TBATS models are used as forecasting tools in various types of time series.

Perone (2022) compared ARIMA, exponential smoothing (ETS), neural network autoregression (NNAR), TBATS and hybrid models to forecast the second wave of Covid-19 hospitalizations in Italy. He found that the best single models were NNAR and ARIMA for patients from both groups of patients, depending on the severity of the illness. However, for patients with mild symptoms, the most accurate were the hybrid models NNAR–TBATS, ARIMA–NNAR, and ARIMA–NNAR–TBATS. Perone concludes that compared to the single models the hybrid statistical models capture a greater number of properties in the medical time series data structure. The predictions seem to suggest interesting practical implications.

Talkhi *et al.* (2021) consider similar forecasting questions with respect to Covid-19 in Iran and also use the TBATS model. This is not the only attempt to forecast using TBATS models. Applying TBATS, ARIMA, their statistical hybrid, and a mechanistic mathematical model combining the best of the previous models, Sardar *et al.* (2020) attempted to predict the daily confirmed cases of Covid-19 across India and in five different Indian states (Delhi, Gujarat, Maharashtra, Punjab, and Tamil Nadu) for the second half of May 2020. The ensemble model demonstrated the best prediction capacity and suggested that daily Covid-19 cases would significantly increase in the forecast window considered. Furthermore, the lockdown measures would be more effective in states with the highest percentages of symptomatic infection.

An interesting contribution using combined TBATS with the support vector machine (SVM) model of minimum and maximum air temperatures applied to wheat yield prediction at different locations in Europe is that of Gos *et al.* (2020). They found that the precision of air temperature prediction improves when using combined SVM/TBATS modelling, compared to pure TBATS or SVM modelling. Depending on the locations, which can be related to different climatic conditions, this improvement was between 3% and 14% for the maximum daily air temperature. The interval of improvement varied between 5% and 25% for the minimum daily air temperature.

Munim (2022) found that in modelling the container freight rate, the TBATS model or a combination of TBATS and SARIMA forecasts are better than the SARIMA and seasonal neural network autoregression (SNNAR) models as well as their combinations, both in training and test-sample forecasts. Munim emphasizes that none of the forecasting methods performs better than the TBATS model. Furthermore, for the robustness of the cross-validation, each test-sample data point is forecast using model re-estimation, which improves the forecast performance of the SARIMA and SNNAR models but not of TBATS.

It follows from this literature overview that there are seasonal and calendar effects in the time series of withdrawals from ATMs. They should be included in the forecast models. Moreover, the literature overview convinces us that TBATS models can be useful. Therefore, we formulated the following hypotheses:

H1: Taking seasonal and calendar effects into account when forecasting withdrawals from ATMs reduces forecast errors. The improvement of forecast accuracy is statistically significant and occurs for both SARIMA and TBATS.

H2: Forecast errors obtained in the TBATS model are smaller than those resulting from using the SARIMA model.

RESEARCH METHODOLOGY

In this part of the article, we will describe the structure of the data used in the analysis. We will also present the methodology and models used in the empirical part of the article. Moreover, we will define the procedure used to compare the models.

Sample and Data Collection

We analyzed the dataset on withdrawals from 74 ATMs covering the period from 1 January 2017 to 31 December 2019, *i.e.* before the outbreak of the Covid-19 pandemic. We wanted to verify the

usefulness of TBATS models in ATM's withdrawal forecasting without facing the possible bias in the data caused by the pandemic.

Referring to other contributions, we checked the basic econometric properties of the time series of the withdrawals. To illustrate the dynamics of examined data, Figure 1 presents the main features of the time series of withdrawals from examined ATMs.[1]
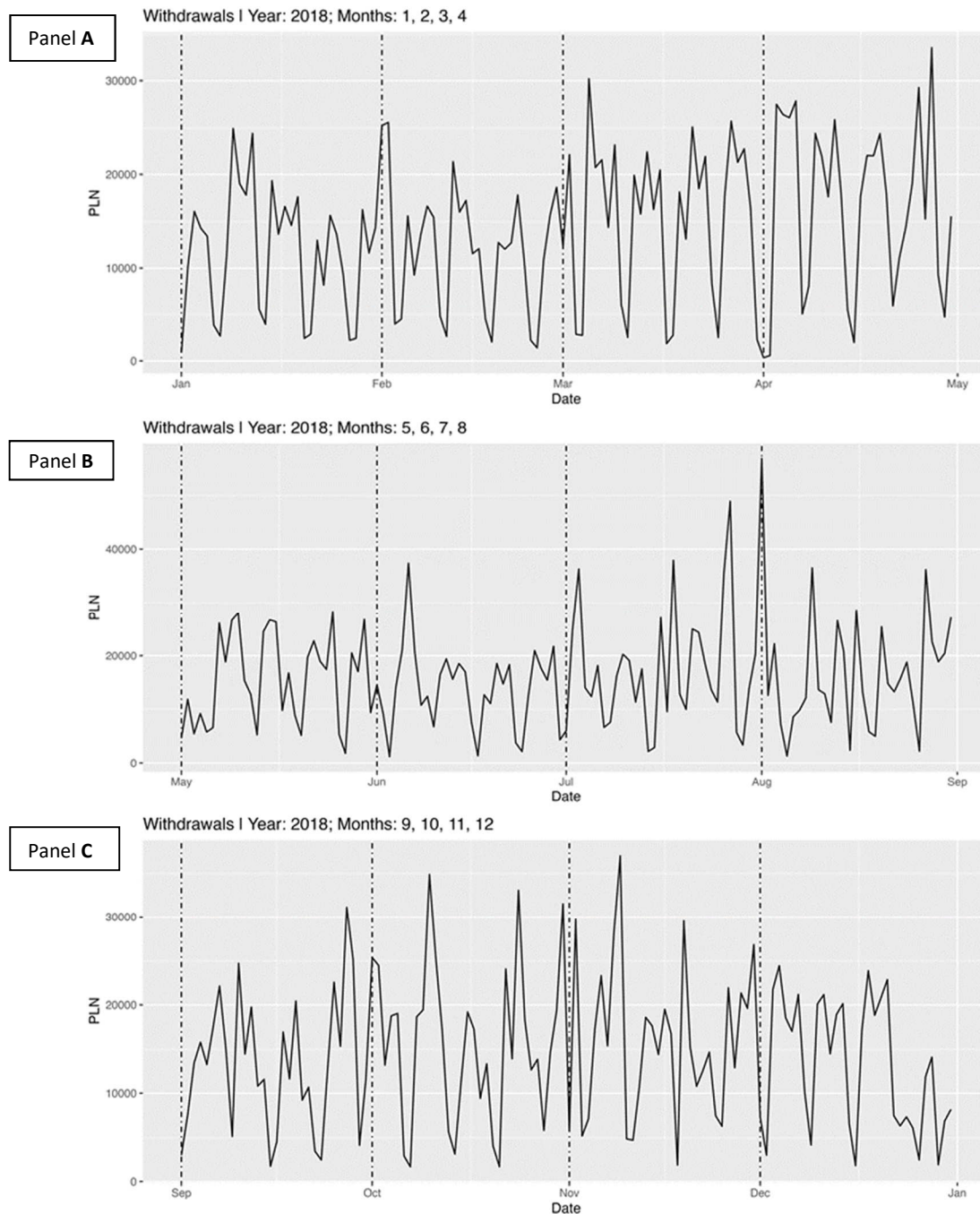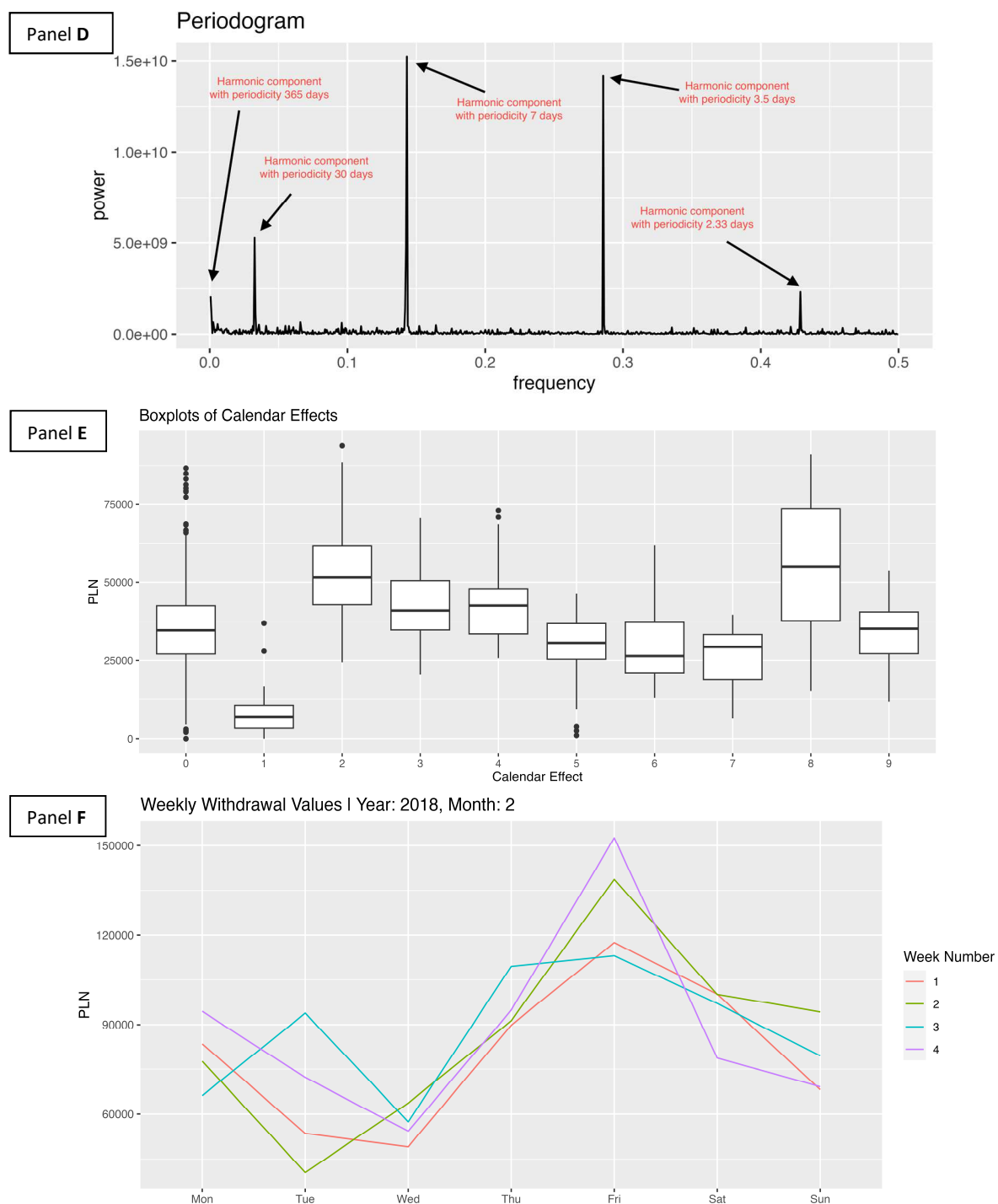
Figure 1. Main features of time series of ATM withdrawals

Note: Panels A-C show 2018 withdrawal data in one-month slices for a particular ATM, Panel D shows a raw periodogram for a particular ATM in the period 2017-2019, Panel E illustrates boxplots of withdrawals for selected nine types of special days (numbers 1-9 on the x-axis) and typical days (0 on the x-axis) for a particular ATM over the examined period, Panel F shows weekly withdrawal data in February 2018 for a particular ATM.

Source: own elaboration.

Figure 1 provides insights on the list of possible effects occurring in the ATM-related dataset. Panels A-C in Figure 1 present the exemplary ATM withdrawal data.[2] The presented time series clearly exhibits seasonal patterns. In the next step, we conducted trend analysis. The main reason for the presence of a deterministic trend in most of the analyzed series on ATM withdrawal was the general trend of decreasing demand for cash in 2017-2020 (see NPB report for the first quarter of 2022), which translated into a decrease in the total daily amount of withdrawals from ATMs. This type of trending behaviour was found for most of the examined ATMs. However, for some ATMs, there was a noticeable increase in the size of withdrawals. This may be due to the development of infrastructure in the neighbourhood of the ATM location or the removal of nearby ATMs. Unfortunately, due to the lack of information on the location of ATMs, it is not possible to verify the reason for this increase in demand for cash at a given ATM. After conducting linear and logistic trend analysis for the 2017-2019 sample, we found that, in general, the logistic trend not only fits best the ATM withdrawals data but at the same time the shape of the fitted trend line, *i.e.* logistic S-curve, seems to correspond to typical stages of ATM development (installation, fast development, stabilization). We did not find a single set of parameters of the trend function that would fit well to majority of the ATM's. A visual inspection of raw periodograms (comp. Figure 1, Panel D) allowed us to obtain insights on possible seasonal and calendar effects occurring in the time series under study. Statistically significant levels of ACF (at 5% level) were found for weekly, monthly, and yearly seasonality for all but one ATM[3] with the dominant pattern found for weekly seasonality (comp. Figure 1, Panels D and F).[4] After scanning the data (comp. Figure 1, Panel E), we decided that the following nine calendar effects should be taken into account in this article:

1. Work-free holidays (such as Easter and Christmas);
2. The tenth day of a month, when wages and salaries are most commonly paid in Poland;
3. The first day of the month;
4. The last day of the month;
5. Trading Sundays;
6. The beginning of a long weekend;
7. The end of a long weekend;
8. The day before the beginning of a long weekend;
9. The day after the end of a long weekend

The individual properties (*i.e.* trends, seasonal and calendar effects) of time series of ATM cash withdrawals were used to construct respective forecasting models, as we focused on out-of-sample forecasts in the study. Each effect presented in Figure 1 was derived based on withdrawal data for the selected ATM that strongly exhibited the given effect. Individual ATMs may vary in terms of intensity of a given effect, *e.g.,* in case of some ATMS the weekly seasonality may be more pronounced then in case of other ATMs. For example, Figure A2 in the appendix presents all the effects discussed in Figure 1 but this time derived for a single randomly selected ATM. The forecasting procedure was fully automated and implemented in the R environment.

Forecasting Models

In the econometric literature, backshift (B) notation is widely used when defining time series models. In particular, this operator allows one to write down ARIMA models more clearly and comprehensively. The operator B backshifts the values of the time series:

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[2] For some examined ATMs, the respective time series on cash withdrawals contained some zeros that corresponded to various potential causes (*e.g.,* ATMs located in shops being closed on non-trade days, random ATM failures etc.). At the same time, the use of a Box-Cox transformation is limited to positive time series. To handle data with zero values, the estimation procedure of TBATS models implemented in the *tbats* function in *forecast* package used inverse hyperbolic sine transformation (Johnson, 1949). Moreover, when calculating the forecast errors, we skipped the dates with known zero withdrawals as such cases would spuriously improve the forecast accuracy.

[3] Complete results of the initial stage of the analysis are available from authors upon request.

[4] On the periodogram, one can also see shocks for frequency 0.284 and 0.428, which are called harmonic shocks and support existence of 3.5 and 2.33-day cycles, respectively. The one-week cycle is a multiple of these two cycles (Bloomfield, 2000).

$$BX_t = X_{t-1}, B^2 X_t = X_{t-2}, \dots, B^n X_t = X_{t-n} \tag{1}$$

in which $(1 - B)$ denotes the difference of order 1, $(1 - B)^2$ denotes the second difference, and $(1 - B)^n$ stands for the nth difference. Taking backshift notation into account, we can define the $ARIMA(p, d, q)$ model in the following way:

$$(1 - \phi_1 B - \cdots - \phi_p B^p) X_t' = c + (1 + \theta_1 B + \cdots + \theta_q B^q) \varepsilon_t \tag{2}$$

in which $X_t' = (1 - B)^d X_t$ denotes the integrated time series, $\phi_1, \dots, \phi_p$ are parameters of $AR(p)$ and $\theta_1, \dots, \theta_q$ are parameters of $MA(q)$, d is the order of differences, and ε_t is white noise.

The SARIMA models are a further generalization of the ARIMA models. The ARIMA models are not able to model data with seasonality. This drawback can be omitted by generalizing the ARIMA into seasonal autoregressive integrated moving average (SARIMA). Using the backshift operator $SARIMA(p, d, q)(P, D, Q)_m$ may be defined as follows:

$$(1 - \phi_1 B - \cdots - \phi_p B^p)(1 - \Phi_1 B^m - \cdots - \Phi_P B^{Pm})(1 - B)^d (1 - B^{Dm}) X_t =$$
$$= c + (1 + \theta_1 B + \cdots + \theta_q B^q)(1 + \Theta_1 B^m + \ \dots \ + \Theta_Q B^{Qm}) \varepsilon_t \tag{3}$$

In (3), the triple (p, d, q) stands for the nonseasonal component of the SARIMA model and $(P, D, Q)_m$ denotes seasonal part of the model. In detail, P stands for seasonal autoregressive order, D denotes seasonal difference order, Q stands for seasonal moving average order, and m denotes the number of time steps for a single seasonal period.[5]

The alternative group of models used in the empirical part of this article comprises the BATS and TBATS models.[6] The name BATS/TBATS is an acronym consisting of four/five letters: T – trigonometric seasonality, B – the Box-Cox transformation, A – ARIMA errors, T – Trend, and S – seasonal components.

The BATS model is a modification of exponential smoothing (double-seasonal Holt-Winters forecasting method). We supplemented this well-known method with the Box-Cox variance stabilizing transformation, ARMA model for the error term and inclusion of T seasonal patterns. The ARMA model allows one to remove the problem of autocorrelation in residuals. In short, the BATS model is a combination of exponential smoothing, the Box-Cox transformation, and errors of the ARMA process with several (not only two) seasonal components.

The following equations (4)-(9) describe the components of the BATS model (De Livera *et al.*, 2011):

$$X_t^\omega = \begin{cases} \frac{X_t^\omega - 1}{\omega} & for \ \omega \neq 0 \\ log(X_t) \ for \ \omega = 0 \end{cases} \tag{4}$$

$$X_t^\omega = l_{t-1} + \varphi b_{t-1} + \sum_{i=1}^{T} s_{t-m_i}^i + d_t \tag{5}$$

$$l_t = l_{t-1} + \varphi b_{t-1} + \alpha d_t \tag{6}$$

$$b_t = (1 - \varphi)b + \varphi b_{t-1} + \beta d_t \tag{7}$$

$$s_t^i = s_{t-m_i}^i + \gamma_i d_t \tag{8}$$

$$d_t = \sum_{i=1}^{p} \phi_i d_{t-1} + \sum_{i=1}^{q} \theta_i \varepsilon_{t-i} + \varepsilon_t \tag{9}$$

in which:

   l_t - denotes local level in time t;
   b_t - component reflecting the short-term trend in time t;
   b - parameter reflecting the long-term trend;
   s_t^i - i-th seasonal component in time t, where $i = 1, \dots, T$;
   d_t - the ARMA(p, q) process;
   ε_t - white noise;
α, β, γ_i - smoothing parameters, where $i = 1, \dots, T$;

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[5] Comprehensive theoretical background for time series modelling (including ARIMA/SARIMA models) is given in detail in Hyndman *et al.* (2008) and Shumway and Stoffer (2010).
[6] A detailed theoretical introduction to BATS/TBATS models is given in a textbook by Hyndman and Athanasopoulos (2021).

φ **-** parameter-suppressing trend.[7]

Equation (4) defines the Box-Cox transformation, where ω is a parameter of the transformation and X_t is observation at time t. Equation (5) is a mathematical formula for the BATS model, consisting of 4 main components described in (9)-(12). Equation (6) is a formula for the local level of time series, (7) is a formula for the short-term trend at time t, (8) defines the i-th seasonal component at time t and (9) shows the formula for $ARMA(p,q)$. The domain of the BATS model is given by expression (10):

$$BATS(\omega, \varphi, p, q, \{m_1, \dots, m_T\}) \tag{10}$$

in which:

ω - the parameter of the Box-Cox transformation;

p, q - time lags of $ARMA(p,q)$;

φ - suppressing parameter;

m_i **-** the length of the i-th seasonal window, $i = 1, \dots, T$.

The TBATS model is a modification of the BATS model. The TBATS model employs the trigonometric model of seasonality. In BATS, it is assumed that m_i ($i = 1, \dots, T$) is a natural number. In TBATS, this parameter can be set to any positive real number. This extension is possible due to the inclusion of a trigonometric model of seasonality:

$$s_t^i = \sum_{j=1}^{k_i} s_{j,t}^i$$
$$s_{j,t}^i = s_{j,t-1}^i cos\lambda_j^i + s_{j,t-1}^{*i} sin\lambda_j^i + \gamma_1^i d_t \tag{11}$$
$$s_{j,t}^{*i} = -s_{j,t-1}^i sin\lambda_j^i + s_{j,t-1}^{*i} cos\lambda_j^i + \gamma_2^i d_t$$

in which:

$s_{j,t}^i$ - stochastic increase in level in the i-th seasonal component, which is necessary to describe the change in the i-th seasonal component in time by means of $s_{j,t}^{*i}$, where $i = 1, \dots, T$, and $j = 1, \dots, k_i$;

γ_1^i, γ_2^i - smoothing parameters;

k_i **-** the number of harmonic components (at frequencies $\lambda_j^i = \frac{2\pi j}{m_i}$ where $j = 1, \dots, k_i$,) necessary for the i-th component seasonal window.[8] The approach is equivalent to index seasonal approaches when $k_i = \frac{m_i}{2}$ for even values of m_i, and when $k_i = \frac{m_i - 1}{2}$ for odd values of m_i.

To summarize, TBATS models are often used for forecasting for several reasons. The Box-Cox transformation makes it possible to stabilize the variance, which is an important advantage in empirical analyses. The model allows one to simultaneously take into account many seasonal components with integer and non-integer lengths of seasonal windows. Function *tbats* in *forecast* package allows for estimating the lengths of seasonal windows as described in De Livera *et al.* (2011). Similarly to BATS, TBATS also takes the autocorrelation of residuals into account.

The abbreviated version of the model with a defined domain is given by:

$$TBATS(\omega, \varphi, p, q, \{\{m_1, k_1\}, \dots, \{m_T, k_T\}\}) \tag{12}$$

in which:

ω - parameter of the Box-Cox transformation;

p, q - time lags of $ARMA(p,q)$;

φ - smoothing parameters;

$\{m_i, k_i\}$ **-** a pair of two parameters: m_i – the length of the i-th seasonal window, k_i – number of Fourier terms for the i-th seasonal effect, where $i = 1, \dots, T$.

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[7] Although all TBATS models examined in this study were fit to detrended ATM withdrawal data, we did not impose any restrictions on the trend/level related parameters in (6) and (7). From various alternatives tested, we decided to use logistic function to remove trend from the raw data and next estimate unrestricted TBATS. As we checked such an approach resulted in better forecast accuracy compared to the case of using TBATS estimated on raw data.

[8] We followed De Livera *et al.* (2011) to specify TBATS model selection procedure, including the choice of the number of harmonics k_i in the trigonometric models. For technical details see Boshnakov and Halliday (2022).

In our computations, we used the open-source statistical software R and IDE RStudio. To estimate SARIMA models, we used the R package *stats*. Calendar and special effects were modelled using dummies in the respective models (Harvey, 1989). The *sarima* function in the core *stats* package allows one to use dummy variables reflecting calendar effects and special days effects. Technically, the estimation of such models is based on using the so-called SARIMAX formulation (also referred to as mean-corrected formulation) of model (3) in which X_t is replaced with $Y_t = X_t - f(t)$, where $f(t)$ can depend on exogenous (e.g., dummy) variables.

To estimate TBATS models, we used the MLE-based estimation procedure described in detail in De Livera *et al.* (2011) and implemented in R in *tbats* function by Slava Razbash and Rob J. Hyndman. The function is available in the *forecast* package. One of the major limitations of all existing implementations of TBATS models, including the one available in *tbats* function in *forecast* package in R, is the lack of possibility of including exogenous variables. To some extent, this drawback may explain why TBATS have not been widely used in forecasting withdrawals from ATMs. To overcome this limitation, we followed a hybrid two-step approach: the TBATS models were estimated on the basis of time series on ATMs withdrawals with calendar and special days excluded. In the second step, the withdrawals on the calendar and special days were separately estimated using basic ARIMA-class models. In further parts of this article, forecasts obtained from such a two-step procedure will be referred to as forecasts from TBATS models extended with calendar and special days. The complete replication code in R illustrating full details on all the econometric models used in our study is available in the Appendix at the end of this article.

Methods of Forecast Comparison

There are standard measures which allow comparing accuracy of the forecasts of the time series obtained in different models. In the case of ATM data, the most popular absolute ex-post verification measures, such as mean squared error (MSE) or mean absolute error (MAE), are often not appropriate since ATM with extremely high levels of cash withdrawals will most likely also exhibit higher levels of absolute forecast errors compared to ATMs with relatively low average withdrawals. The reason is differences in the scale of the ATM-related time series being modelled. To support this claim, one could recall the case of two particular ATMs in the dataset – the one with the highest average daily cash withdrawal (denoted in H) and the one with lowest daily withdrawal (L). As we tested MAE for H were on average 2276% higher than their counterparts calculated for L. Figure A1 in the Appendix illustrates this phenomenon in detail by showing mean levels of monthly cash withdrawals with respective levels of MAE. To avoid or reduce the problem of scale in the case of ATMs with significantly different values, we used the following relative measures (Makridakis *et al.*, 1998):

− mean absolute percentage error – MAPE:

$$MAPE(X_t, t_0, h) = \sum_{i=0}^{h-1} \left| \frac{X_{t_0+i} - \hat{X}_{t_0+i}}{X_{t_0+i}} \right| \tag{13}$$

− symmetric mean absolute percentage error – SMAPE:

$$SMAPE(X_t, t_0, h) = \sum_{i=0}^{h-1} \left| \frac{X_{t_0+i} - \hat{X}_{t_0+i}}{\frac{1}{2}(X_{t_0+i} + \hat{X}_{t_0+i})} \right| \tag{14}$$

in which:

X_{t_0+i} - actual value at time $t_0 + i$;
$\hat{X}_{t_0+i}$ - forecasted value at time $t_0 + i$;
h - forecast horizon;
t_0 - start of the forecast window.

Although the MAPE measure is one of the most popular ones, it also has some drawbacks. The most serious one is its asymmetry. Mean absolute percentage error gives higher results in the case of overestimated forecasts which may happen if, for example, a given ATM unexpectedly stops working for some time. In such a situation, the denominator in (13) becomes very low and MAPE suggests that the forecasting properties of the underlying model are poor, although this effect is due to an unexpected event, not the model itself. This drawback was removed in a modification of MAPE called symmetric MAPE (SMAPE). Symmetric MAPE also has some drawbacks. It is a proper

measure only when both actual values and forecasted values exhibit the same sign. An additional reason for choosing SMAPE is the fact that – contrary to MAPE – this measure is used by the network operators which provided the data for this research.

The accuracy of the forecasts obtained using the SARIMA/TBATS models (both with and without calendar effects) was tested by comparing forecast errors with a one-month and two-week (14 days) forecast horizon. One-month forecasting periods are used by the data provider in the process of managing the ATM network. Therefore, this period was chosen in order to compare the results of our study with internal forecasts of the data providing company. In addition, 14-day forecasts were given attention in our study because in case of ATMs, which are replenished more than once a week, such a forecast horizon seems useful from the operational point of view. To take yearly seasonality into account, the estimation window was set as a two-year period preceding the forecast window, *i.e.* the estimation window for each model included 730 observations. Monthly forecasts were conducted for full months (*i.e.*, for each forecasted month the parameter h was set equal to the number of days in a given month and t_0 was set to the first day of the given month in (13) and (14)). Two-week forecasts were conducted for 12 selected 14-day periods. The periods were chosen in a way that they included different types of calendar effects and other special effects (*i.e.*, for each forecast the h was set equal to 14 and t_0 was set equal to a given starting day of the forecast windows listed in Table 2). To describe periods of the forecasts, we included information on the types of special days in Table 1 and Table 2. Given the specification shown in Table 1 and Table 2 one may claim that analysis of results of testing the accuracy of forecasts can help find the models that give best forecasts over periods with different types of calendar effects.

Table 1. Characteristics of monthly forecasts

Period number	Forecasts periods	Calendar effects in the given periods
1	January	One one-day church holiday, winter holiday, one Sunday trading day
2	February	One Sunday trading day
3	March	One Sunday trading day
4	April	Easter holiday, two Sunday trading days
5	May	Long weekend, one Sunday trading day
6	June	Long weekend, beginning of summer holidays, one Sunday trading day
7	July	Summer holiday, one Sunday trading day
8	August	Summer holiday, the beginning of the month, long weekend
9	September	Beginning of the school year
10	October	Beginning of the academic year
11	November	Two long holidays because of church and national holidays
12	December	Christmas holidays, trading Sundays

Note: Only special events in a given month are listed in the above table. We omitted events occurring every month *i.e.* one trading Sunday, the first and the last day of the month, and the tenth day of the month.
Source: own elaboration.

To verify our hypotheses concerning the accuracy of the forecasts obtained by means of TBATS and SARIMA with calendar effects, we compared the descriptive statistics for MAPE and SMAPE. These comparisons were made separately for forecasts in the selected periods and also jointly for all forecasts. The analysis of four models (*i.e.* the basic SARIMA model (denoted by S), the SARIMA model taking calendar and special effects into account (SARIMA with dummies; the model is denoted by S_CE), the basic TBATS (T) model and basic TBATS model extended with calendar and special effects (T_CE), involved a comparison of the ex-post accuracy of forecast error. Moreover, the forecast errors for each ATM during the whole period under consideration were compared. The sample included 74x12=888 MAPE errors and the same number of SMAPE errors for monthly forecasts. Analogous analysis was performed for two-week forecasts. The comparisons were made in pairs of models, *i.e.* S_CE vs S, T vs S, T_CE vs T and T_CE vs S_CE. Focusing on these pairs enables formulating conclusions about the feasibility of the methods used in forecasting ATM withdrawal data.

Table 2. Characteristics of two-week forecasts

Period number	Forecasts periods	Calendar effects in the given periods
1	17.01-30.01	End of the month, trading Sunday, occasional holidays
2	5.02-18.02	10th day of the month, occasional holiday
3	25.03-7.04	Turn of the month, trading Sunday
4	11.04-24.04	Easter holidays
5	1.05-14.05	Beginning of the month, 10th day of the month, long weekend
6	17.06-30.06	Long weekend, Beginning of the summer holidays, trading Sunday
7	6.07-19.07	Summer holidays
8	1.08-14.08	Summer holidays, beginning of the month, every 10th day of the month
9	26.08-8.09	Turn of the month, beginning of the school year
10	01.10-14.10	Beginning of the month, beginning of the academic year
11	28.10-11.11	Turn of the month, two long weekends
12	16.12-29.12	Christmas period, trading Sundays

Source: own elaboration.

From the point of view of ATMs management, the best model should ensure the highest accuracy of out-of-sample forecasts as this may help to define strategies allowing for minimalization of operational costs. On the other hand, model specification is typically based on analyzing in-sample fit. In this study, we examined both of these issues. However, we paid attention mainly to checking the accuracy of out-of-sample forecasts, because this criterion is used in practice by managers of ATM networks.

RESULTS AND DISCUSSION

The results of the empirical analysis will be presented with respect to the accuracy measures and horizons of the forecasts. First of all, the statistics for forecast errors will be presented and evaluated. Then, the results of the comparison of forecast accuracy for each ATM will be summarized, depending on the type of error and the forecast horizon.

Comparison of MAPE for Monthly Forecasting

Table 3 presents the basic descriptive statistics of MAPE for monthly forecasts for 74 ATMs. To make the data easier to read, Figure 2 additionally shows a radar chart of mean MAPE calculated in selected months with respect to the type of model applied.

Table 3. Descriptive statistics of MAPE for monthly forecasts

Months	Mean				Median				Standard deviation			
	S [%]	S_CE [%]	T [%]	T_CE [%]	S [%]	S_CE [%]	T [%]	T_CE [%]	S [%]	S_CE [%]	T [%]	T_CE [%]
January	48.53	39.14	39.41	35.22	54.23	38.00	38.67	33.55	23.3	25.3	24.5	21.57
February	34.87	30.88	30.01	29.86	32.15	26.89	27.51	27.37	18.9	19.8	18.5	15.79
March	33.31	29.84	31.22	31.36	32.41	27.20	29.91	29.34	20.7	20.3	21.1	19.41
April	51.79	35.88	42.80	33.22	61.70	33.53	44.82	30.90	26.1	20.1	25.6	19.95
May	44.68	32.67	42.27	32.34	47.42	32.14	41.30	30.81	25	20.1	19.5	16.81
June	40.83	32.16	33.85	29.93	39.38	29.55	34.29	29.21	18.9	13.6	20.9	17.61
July	36.92	31.17	31.04	30.61	37.21	30.32	28.89	32.52	22.1	21.4	20.5	21.41
August	39.50	32.52	34.21	29.45	38.03	29.12	31.45	27.33	21.7	19	20.7	17.82
September	33.49	29.38	30.26	29.14	33.14	25.95	29.31	26.21	20.5	16.8	12.8	11.74
October	36.29	29.21	31.73	29.99	35.97	27.85	27.87	26.64	22.6	22	17.5	15.07
November	47.97	33.53	41.93	31.55	47.04	30.95	42.25	30.91	19.9	16.9	20.3	16.52
December	53.73	43.76	52.11	40.64	85.07	46.21	66.71	41.77	25.5	24.7	17.5	13.51
Total	41.82	33.34	36.74	31.94	45.31	31.48	36.91	30.55	22.10	20.01	19.95	17.27

Note: The lowest values for each month and each descriptive statistics are highlighted.
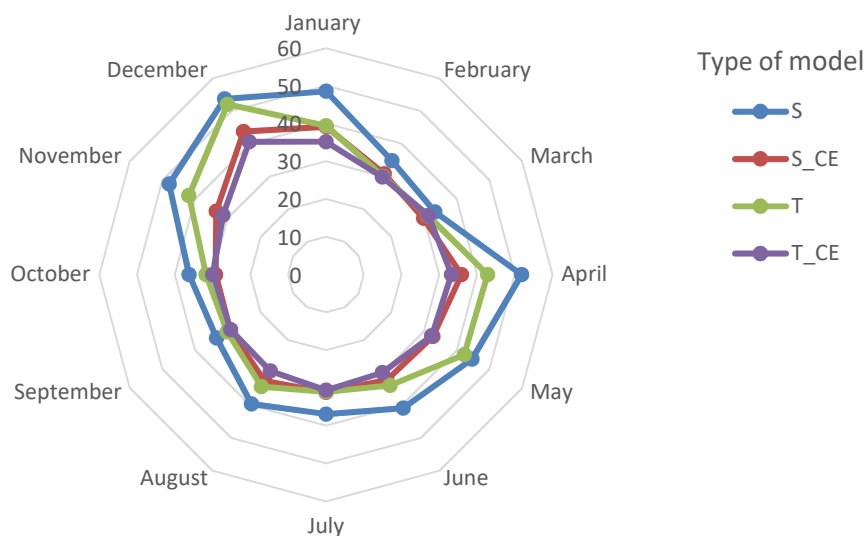Source: own elaboration.

Figure 2. Radar chart for mean MAPE values (in %) in each month for different methods
Source: own elaboration.

Analysis of Table 3 and Figure 2 allows one to conclude that the lowest values of relative forecasts error were usually found for TBATS model extended with calendar and special effects. The exception was the forecasts for March and October. The forecasting performance of other models, *i.e.* those not taking calendar effects into account, was visibly worse as the lowest relative forecast error was never achieved for such models. The average MAPE calculated for all forecasts (*i.e.* for all months) was lowest in the case of the T_SE model and did not exceed 32%. It was about 1.4% lower than average MAPE calculated for S_CE model and almost 5% lower than the mean value of MAPE for the basic TBATS model. From a comparison of median of MAPE for 74 ATMs, it follows that the minimal median was also usually obtained for the T_CE model. For this model, the lowest median of MAPE was achieved in eight out of 12 months. In the case of three out of the remaining four months, the best model (in terms of the lowest median value of MAPE) was S_CE, and in only one month (July) the basic TBATS model was found to have the lowest median of MAPE. We should emphasize that the T_CE was found to provide more accurate forecasts in months with a smaller number of special days (*i.e.* March or October). The standard deviation of MAPE errors suggests that this measure exhibits the lowest volatility for monthly forecasts obtained via T_CE. The volatility of MAPE for the basic TBATS model is lower than for SARIMA. Considering calendar and special days effects visibly reduces the average MAPE value both in SARIMA and TBATS models. In the case of the SARIMA model, the inclusion of calendar effects and special days effects decreased the mean value of relative forecast errors by approximately 8% and in the case of TBATS – by around 5%.

To summarize, the basic TBATS model and TBATS model extended with calendar and special effects perform better with respect to forecasting daily withdrawals from ATMs than the SARIMA model (comp. Figure 2). We showed that including dummies (*i.e.* taking calendar and special effects into account) considerably reduces average errors in both SARIMA and TBATS frameworks. To test the statistical significance of these results, we conducted a series of Friedman tests applied to test the significance of differences in mean MAPE obtained from four pairs of models: T and S, T and T_CE, S and S_CE and finally T_CE and S_CE. The tests confirmed statistically significant differences between mean MAPE in the case of all pairs of models compared, except the pair T_CE and S_CE.[9] These results imply that basic TBATS allows obtaining more accurate forecasts compared to basic SARIMA. Moreover, they provide grounds for claiming that taking seasonal and calendar effects into account when forecasting withdrawals from ATMs significantly reduces forecast errors. Significant improvement in forecast quality was observed both for SARIMA and TBATS. The TBATS forecasts errors are slightly smaller than those resulting from SARIMA models. However, this result was found statistically insignificant (p-value in Friedman test equal to 0.42).

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[9] Complete results of conducting Friedman test for all forecasts horizons are available from the authors upon request.

Comparison of SMAPE for Monthly Forecasts

To some extent, values of SMAPE for the monthly forecasts presented in Table 4 and Figure 3 confirmed the conclusions driven after the analysis of levels of MAPE. As far as SMAPE is concerned, the best monthly forecast (the lowest average relative forecast error) was obtained using TBATS model extended with calendar and special effects. The global average value of SMAPE for this model was 29.45% and was 1.5% lower than the corresponding average for forecasts obtained using S_CE, and over 2% lower than its counterpart obtained from the TBATS model. In this context, SARIMA's performance was the worst. Analyzing forecasts for particular months, we can formulate slightly different conclusions compared to the case of MAPE. The T_CE was the best with respect to SMAPE in the case of the nine months under consideration. However, in the other three months, basic TBATS was better. In none of the cases tested the minimal value of SMAPE was found for SARIMA models. In the case of the median of SMAPE, slightly better results were obtained using SARIMA with calendar effects.

Table 4. Descriptive statistics of SMAPE for monthly forecasts

Months	Mean				Median				Standard deviation			
	S [%]	S_CE [%]	T [%]	T_CE [%]	S [%]	S_CE [%]	T [%]	T_CE [%]	S [%]	S_CE [%]	T [%]	T_CE [%]
January	45.86	33.36	31.92	31.69	46.23	32.10	30.42	29.86	18.08	19.64	13.65	11.13
February	35.50	30.63	28.65	29.78	46.23	32.10	30.42	29.86	17.87	20.61	17.91	10.69
March	34.23	30.86	28.75	29.07	32.70	29.50	26.60	27.88	17.82	18.50	21.27	12.17
April	43.48	33.69	34.20	30.56	42.46	31.01	33.73	28.81	11.87	10.75	16.31	10.73
May	42.59	33.85	34.50	31.95	40.75	32.92	32.91	29.88	13.52	13.62	16.24	11.15
June	38.76	32.44	31.85	29.68	38.16	32.46	29.67	28.98	11.90	11.63	14.57	8.03
July	35.05	28.71	27.74	28.41	32.91	27.67	27.42	27.37	13.17	12.11	17.15	10.04
August	34.78	29.29	30.96	26.91	33.70	27.86	27.90	25.79	13.48	12.65	13.09	9.75
September	33.15	27.47	29.81	26.93	33.16	25.52	27.49	25.74	10.27	9.86	15.11	8.60
October	31.61	26.83	29.08	26.50	30.85	25.26	28.13	25.39	11.88	11.94	13.31	7.61
November	37.41	29.44	31.97	27.40	35.02	27.77	30.65	25.62	9.16	10.90	12.94	8.81
December	43.01	35.03	39.75	34.52	42.11	32.98	38.65	33.98	11.27	11.08	13.43	8.92
Total	37.95	30.97	31.60	29.45	37.86	29.76	30.33	28.26	13.36	13.61	15.42	9.80

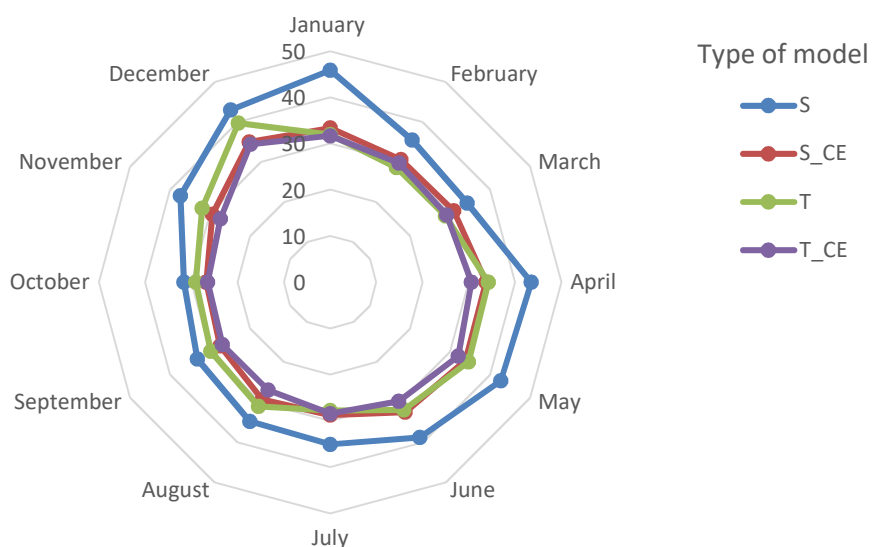Note: In the Table the lowest values are highlighted.
Source: own elaboration.

Figure 3. Radar chart for the means of SMAPE (in %) in particular months
Source: own elaboration.

In the case of September, October, and December, the median of SMAPE was the lowest for S_CE. However, these values were similar to the corresponding values obtained from T_CE. Global standard deviation of SMAPE was lowest in the case of the T_CE model and reached the level of 9.8% – which is considerably lower than in the other three models.

It follows from this part of the analysis that calendar and special effects have an important impact on the accuracy of forecasts. Therefore, one may claim that these effects should be taken into account in modelling ATM withdrawals.

We demonstrated that usually T_CE provides slightly better forecasts than S_CE. However, in February, March, and July (in these months there are only a few calendar effects) the basic TBATS model is more accurate than TBATS model extended with calendar and special effects. This convinces us that in the case of periods without strong calendar or special effects, basic models with no additional exogenous variables seem better alternatives for the purpose of forecasting. Similarly to the case of MAPE, we run a series of Friedman tests to check statistical significance of differences between mean SMAPE obtained from particular models. Only in the case of the pair S and S_CE the means of SMAPE were significantly different.

Comparison of MAPE for Two-week Forecasts

The results for two-week forecasts (Table 5, Figure 4) differed considerably from those obtained for forecasts with a monthly horizon. For two-week forecasts, SARIMA with dummies gave better results than T_CE. Both mean and median values of MAPE from this model showed the lowest value in seven periods under consideration. This effect was most visible at the turn of August and September and at the beginning of October. The difference in accuracy of forecast was approximately 5% in favor of S_CE model. The reason behind this phenomenon is probably the effects of the beginning of the school year and academic year – these are not seasonal. Global means and medians of MAPE are similar for S_CE and T_CE. Among models tested, the average standard deviation of MAPE of T_CE is the lowest. However, taking particular periods into account MAPE obtained in T_CE is smallest just in six out of 12 cases. Similarly to the case of monthly MAPE, we run a series of Friedman tests to check the statistical significance of differences between mean two-week MAPE obtained from particular models. The results led to similar conclusions as in the case of monthly MAPE.

Table 5. Descriptive statistics of MAPE for two-week forecasts

Period	Mean				Median				Standard deviation			
	S [%]	S_CE [%]	T [%]	T_CE [%]	S [%]	S_CE [%]	T [%]	T_CE [%]	S [%]	S_CE [%]	T [%]	T_CE [%]
17.01-30.01	47.53	35.34	35.03	33.79	50.18	35.28	35.88	30.13	24.56	23.37	22.66	21.31
5.02-18.02	42.98	45.16	32.83	26.69	41.53	46.98	30.37	24.75	19.86	21.12	17.89	17.52
25.03-7.04	32.14	28.63	34.18	31.93	30.28	27.45	32.11	29.64	16.87	17.77	17.14	19.25
11.04-24.04	47.12	39.98	50.04	40.90	107.41	40.30	73.22	41.35	121.43	74.99	27.86	22.70
1.05-14.05	52.77	35.42	52.09	37.91	62.14	33.34	59.66	36.59	24.66	19.12	24.81	19.62
17.06-30.06	41.45	31.35	44.15	32.56	43.84	29.02	45.19	29.70	26.24	15.88	21.78	14.67
6.07-19.07	34.46	28.75	37.73	38.01	34.35	29.14	36.58	37.78	22.09	21.49	24.24	23.20
1.08-14.08	41.08	26.86	33.44	25.66	41.05	25.10	32.88	25.06	24.25	22.16	21.49	22.43
26.08-8.09	32.18	27.48	34.36	32.64	31.73	26.40	34.40	32.77	20.61	21.60	20.96	20.83
01.10-14.10	33.29	27.15	36.59	32.53	30.22	24.25	32.48	28.98	18.13	15.95	18.59	16.92
28.10-11.11	53.90	33.02	47.48	32.54	66.51	31.33	54.62	31.46	25.04	19.81	26.41	20.97
16.12-29.12	52.02	51.95	53.29	51.18	149.31	60.96	122.46	60.62	19.84	25.60	22.76	25.62
Total	42.58	34.26	40.93	34.69	57.38	34.13	49.15	34.07	30.30	24.91	22.22	20.42

Note: In the Table, the smallest values for each forecasting period and each descriptive statistic are highlighted.
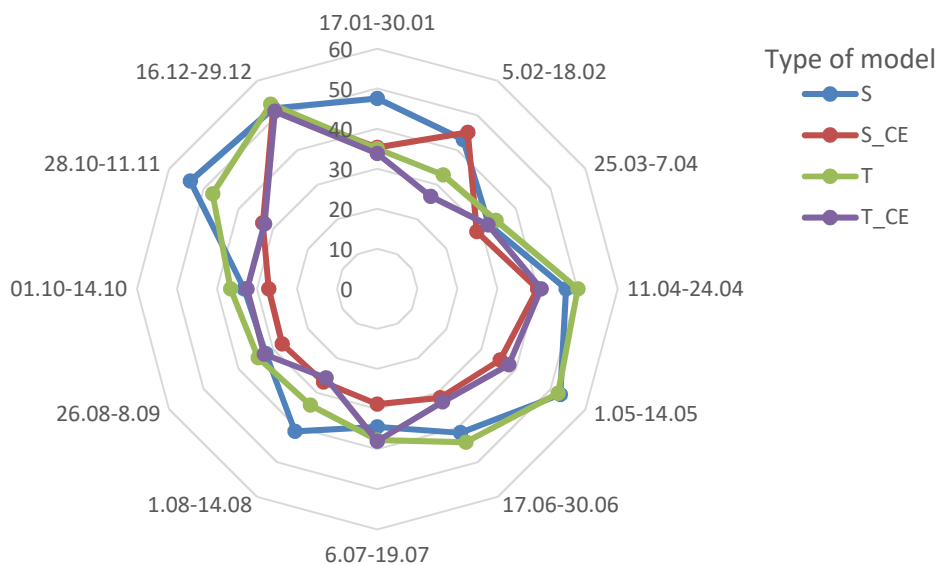Source: own elaboration.

Figure 4. Radar chart of mean values of MAPE (in %) for two-week forecasts
Source: own elaboration.

Comparison of SMAPE for Two-week Forecasts

Global mean SMAPE for two-week forecasts was the smallest for SARIMA models with dummies (Table 6, Figure 5). For the S_CE model, the means of SMAPE for particular periods were only slightly (approximately 0.1%) lower than the corresponding values obtained from the T_CE model. However, the S_CE model turned out to be more accurate than T_CE in seven out of 12 cases. A similar regularity was found when comparing medians of SMAPE. It is in favour of the T_CE models that the volatility of errors was lower than its counterpart obtained from S_CE in nine out of 12 forecast periods.

Table 6. Descriptive statistics of SMAPE for two-week forecasts

Period	Mean				Median				Standard deviation			
	S [%]	S_CE [%]	T [%]	T_CE [%]	S [%]	S_CE [%]	T [%]	T_CE [%]	S [%]	S_CE [%]	T [%]	T_CE [%]
17.01-30.01	39.25	31.52	32.46	30.07	38.00	29.30	32.25	27.16	17.82	16.86	18.24	9.01
5.02-18.02	42.10	37.48	32.87	26.89	39.83	36.40	30.21	25.32	20.23	12.71	12.12	9.13
25.03-7.04	33.26	29.95	35.21	30.92	31.42	27.61	33.99	29.32	12.63	10.97	17.27	10.40
11.04-24.04	53.57	35.08	45.36	34.53	55.70	32.81	45.80	33.19	14.73	11.88	15.26	12.35
1.05-14.05	50.26	37.47	41.92	37.47	53.15	37.05	40.17	36.52	15.90	13.57	16.05	12.91
17.06-30.06	37.16	30.81	39.19	31.91	36.21	28.82	36.45	29.30	13.51	13.02	14.83	13.16
6.07-19.07	34.07	27.92	33.58	33.44	33.43	26.54	32.60	32.53	15.02	11.40	17.99	11.61
1.08-14.08	39.79	28.19	34.34	26.82	38.05	24.94	29.98	24.19	17.29	14.46	13.55	10.46
26.08-8.09	33.07	27.82	35.22	30.83	31.82	24.31	32.84	30.05	11.36	11.50	15.32	8.91
01.10-14.10	31.12	26.57	34.16	30.77	30.43	24.52	32.49	27.67	12.66	12.67	15.44	10.24
28.10-11.11	48.47	32.34	39.72	32.69	47.64	31.41	39.65	30.27	13.35	12.33	15.89	10.34
16.12-29.12	59.47	43.98	53.54	44.05	60.57	42.63	56.03	44.70	14.61	10.60	17.48	9.08
Total	41.80	32.43	38.13	32.53	41.36	30.53	36.87	30.85	14.92	12.66	15.79	10.63

Note: In the Table the lowest values are highlighted.
Source: own elaboration.

Based on the presented comparison of statistics of relative forecast errors, we may see that taking calendar effects (dummies) in the SARIMA model into account significantly improved the forecast accuracy for the horizons analyzed. Extending TBATS with calendar and special days effects improved the forecast accuracy in the case of two-week forecasts. Comparing SARIMA and TBATS both without dummies (not taking calendar effects into account) implies that TBATS-based forecasts are more accurate

than the SARIMA-based ones. One of possible explanations is that TBATS allows modelling multiple seasonal patterns at the same time, it is not limited to just one pattern as in SARIMA. In the case of both models extended with dummies, the results were not unequivocal. In the case of monthly forecasts, we found smaller forecast errors for the TBATS model extended with calendar and special effects. However, in the case of two-week forecasts, SARIMA with dummies provided more accurate forecasts. Analogously to the case of two-week MAPE, we run the series of Friedman tests and obtained similar conclusions.
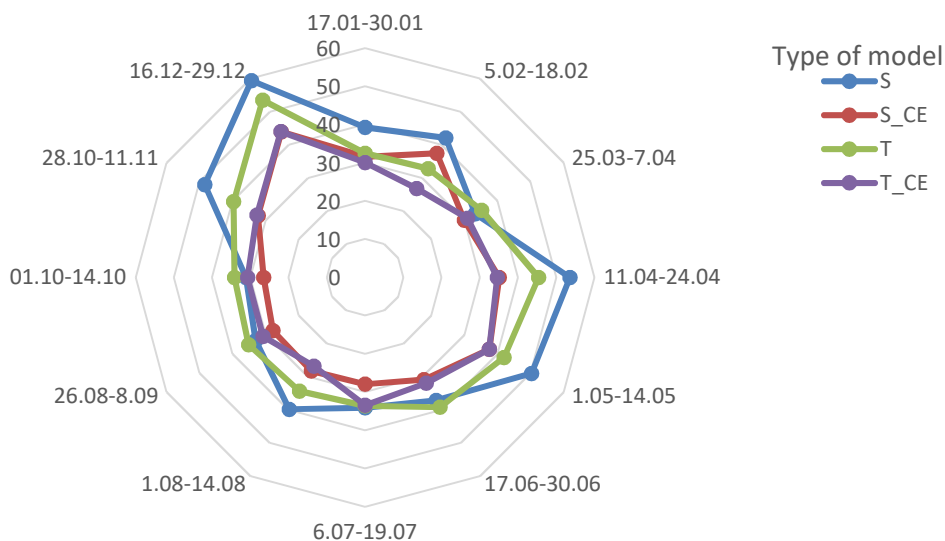
Figure 5. Radar chart of mean values of SMAPE (in %) for two-week forecasts
Source: own elaboration.

Results of Comparing Forecasts for Particular ATMs

The results in the previous sections concerning the quality of the models used to forecast withdrawals were not unequivocal. Therefore, we conducted additional, extended analyses to evaluate the feasibility of the methods and models. This analysis allowed us to compare the MAPE and SMAPE of forecasts for each ATM and each period. A comparison of forecasts was made for four pairs of models. The results are presented in Table 7.

Table 7. Comparison of the pairs of models

Comparison of the pairs of models	Monthly forecasts		Two weeks forecasts	
	MAPE	SMAPE	MAPE	SMAPE
T *vs* S	73.3%	76.9%	66.2%	68.5%
T_CE *vs* S_CE	59.3%	61.4%	48.4%	51.8%
S_CE *vs* S	95.7%	97.1%	92.9%	92.7%
T_CE *vs* T	75.8%	69.9%	83.0%	84.0%

Source: own elaboration.

As one can see in Table 7, monthly MAPE obtained from TBATS forecasts were better in 73.3 % pairs. This effect was even stronger for SMAPE (76.9%). In the case of two-week forecasts, TBATS also provided more accurate forecasts than SARIMA (the difference is about 7%-8%). Compared to S_CE the T_CE model turned out more accurate in about 60% of pairs (MAPE and SMAPE). A comparison of the accuracy of models taking calendar effects into account, with the basic models, *i.e.* pairs. S_CE *vs* S and T_CE *vs* T, shows that extended models are significantly better than basic ones. In more than 90% of cases tested, SARIMA models with dummies are more accurate than basic SARIMA. As we showed in previous sections, these regularities were confirmed by Friedman test.

To summarize, the accuracy of forecasts of SARIMA and TBATS extended with calendar effects was similar. Only in particular cases, the TBATS model extended with calendar and special effects outperformed SARIMA in terms of forecast accuracy, albeit this result was not found to be statistically significant.

CONCLUSIONS

Forecasting withdrawals from ATMs is an important part of managing an ATM network. Managers of ATM networks try to implement solutions that improve forecasting procedures to reduce the cost of replenishing ATMs. Proper forecasts of the cash necessary for ATMs reduce the operational costs of the networks.

In this study, a possible use of TBATS models to forecast withdrawals from ATMs was investigated. In practice, the SARIMA model is widely used as a forecasting tool. Our goal was to compare the SARIMA model with the TBATS model, both estimated with and without taking into account calendar and special effects. The main focus of this study was to verify the impact of calendar and seasonal effects on the forecast accuracy. We identified calendar and seasonal events (*e.g.,* holidays) and attempted to establish their impact on the forecast accuracy.

The empirical results confirmed that in most cases extended models are more accurate (lower MAPE and SMAPE values) compared to basic models. The hypothesis that the TBATS model is better (*i.e.* ensures lower values of MAPE and SMAPE) was verified only to some extent. When calendar effects were omitted, TBATS delivered forecasts of considerably better accuracy than SARIMA. After taking calendar effects into account the TBATS model was only slightly better than SARIMA (lack of statistical significance). Noteworthy, the TBATS model is used rarely as a forecasting tool by ATM networks. The results of this study may encourage further studies on the applications of TBATS models for forecasting the cash necessary in ATMs and in this way improve the network management. One observation is worth to be noted here. As we proved the forecasts obtained from basic TBATS models are in general significantly more accurate compared to the forecasts from basic SARIMA models. At the same time, the accuracy of the forecasts was nearly identical when calendar and special days are taken into consideration. Since existing implementations of TBATS models in statistical software do not allow for inclusion of exogenous variables, one could follow the idea of the hybrid approach presented in this article to incorporate the calendar and special days effects into TBATS framework. In our opinion, a desired direction of further research would be to focus on extending the range of possible formulations of TBATS models available in widely-used econometric software (*e.g.*, R), especially in terms of the inclusion of time dummies.

This research suffers from several other limitations. The accuracy of forecasts may have depended on the location of the ATM. We can hypothesize that in some types of locations taking calendar days (*e.g.,* the day of the month) into account can reduce forecast errors. Because of the lack of data on the location of individual ATMs, we were unable to check the impact of this parameter on the improvement of forecast accuracy.

Another limitation of this research is the fact that the data came from only one city. Future research should be conducted to verify the possible applications of the models in particular types of locations. Finally, an interesting direction of future research would be to study the benefits of analyzing the usefulness of probabilistic forecasts (not only point forecasts as in this article) in the problem of managing ATMs network.

This study may inspire further, more complex analysis of TBATS models with respect to employing this type of model in forecasting cash demand in ATMs. This type of research may be useful for managers who estimate the demand for cash in ATM networks and branches of banks.

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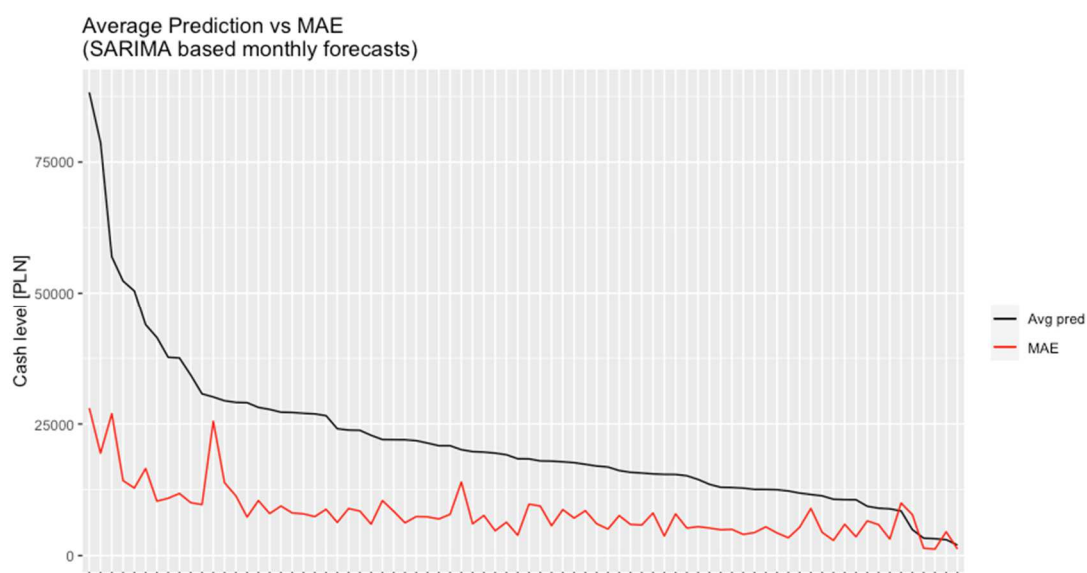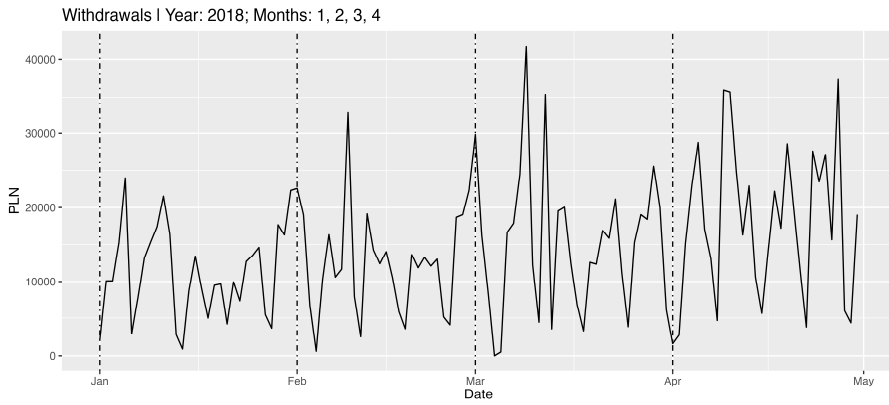
Appendix A1:

**Figure A1. Average levels of monthly cash withdrawals with respective levels
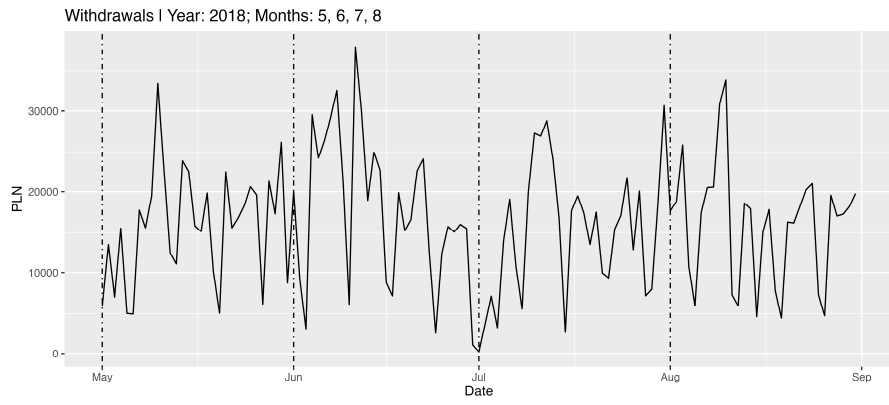of SARIMA-based MAE for 74 ATMs tested**
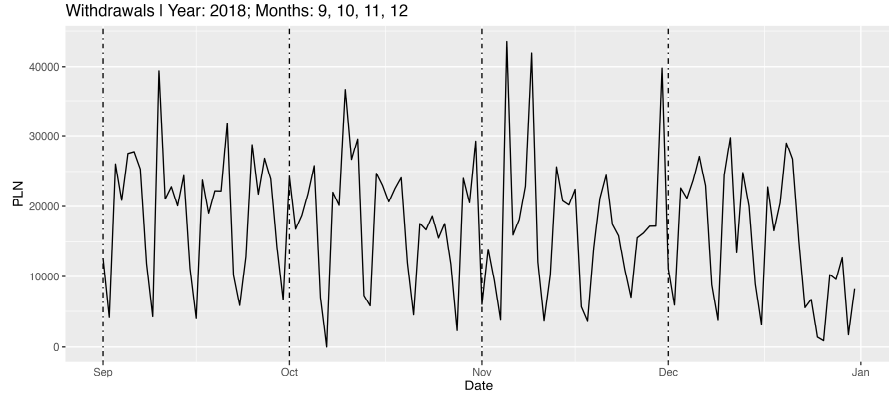Source: own elaboration.

Appendix A2:

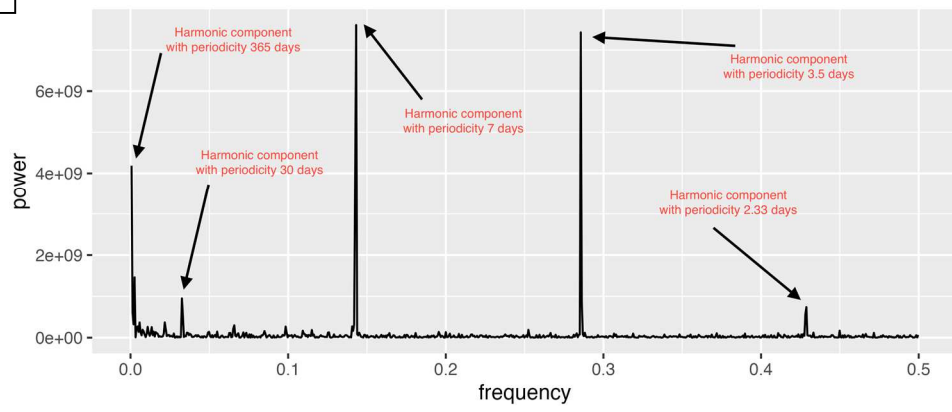Panel **A**

Withdrawals | Year: 2018; Months: 1, 2, 3, 4

Panel **B**

Withdrawals | Year: 2018; Months: 5, 6, 7, 8

Panel **C**

Withdrawals | Year: 2018; Months: 9, 10, 11, 12

Panel **D**
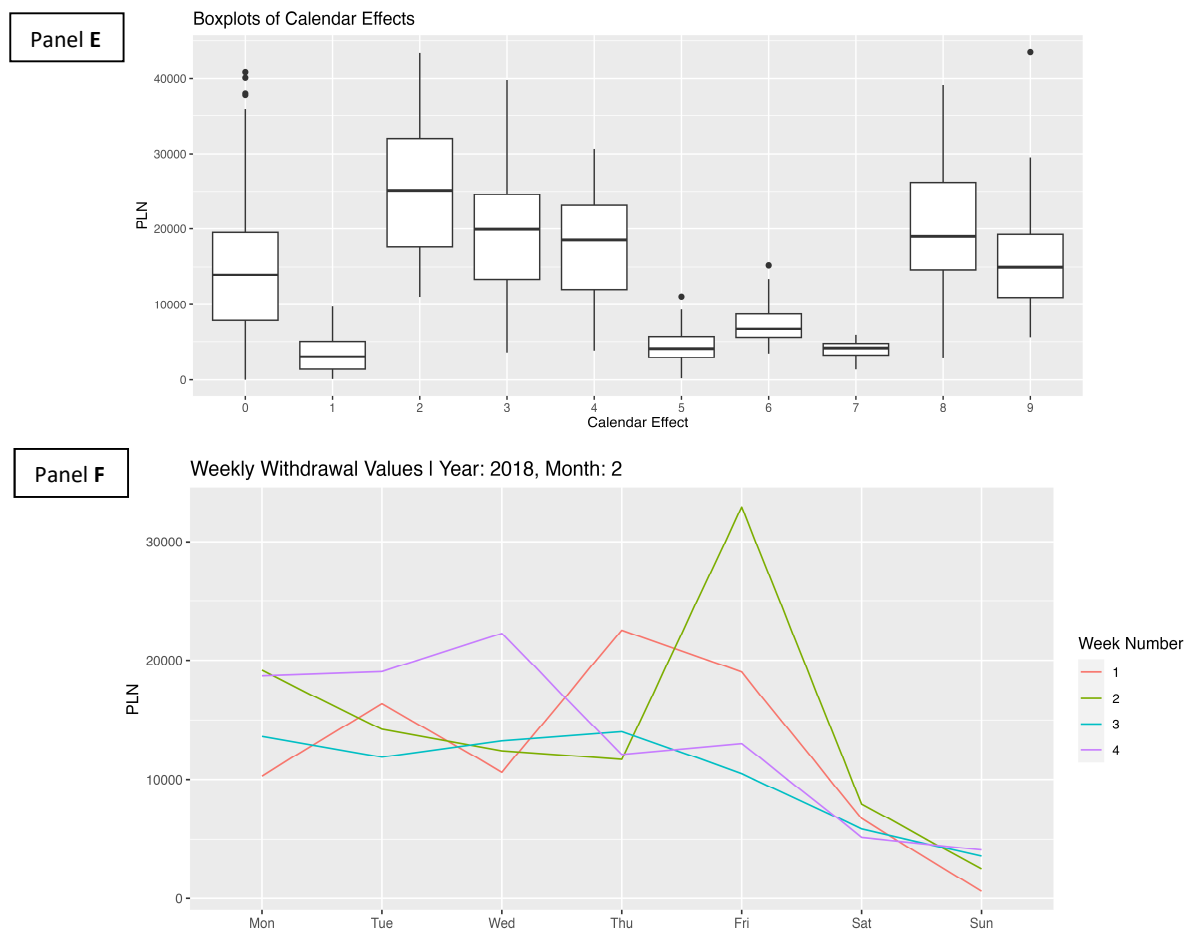
Periodogram

Panel **E**

Panel **F**

Figure A2. Main features of time series of withdrawals from a randomly selected ATM
Notes: The Figure presents all the effects discussed in detail in Figure 1 but this time derived for a single randomly selected ATM.
Source: own elaboration.

Appendix A3:

The R scripts used in this study may be downloaded from:

https://onedrive.live.com/?v=validatepermission&id=7A073B0828CAC72F%21252218&challengeToken=AI2FhJ7R7MeAoVo

(password: agharticle1321)

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The contribution share of the authors is equal and amounts to 25% for each. HG, MS, KS, ŁL – conceptualisation, discussion; HG, MS – literature writing; MS, KS, ŁL – methodology, calculations.

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Conflict of Interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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