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MARKETING MOTIVATIONS INFLUENCING FOOD CHOICE IN 16 COUNTRIES: SEGMENTATION AND CLUSTER ANALYSIS*

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Abstract. Food behaviour is governed by different kinds of motivations, some of individual nature and others related with the external food environment. This study investigated the eating motivations in sixteen countries with respect to commercial and marketing influences on food choices. The questionnaire survey was developed between September 2017 and June 2018, via online tools, targeting a convenience sample of residents in sixteen countries (Argentina, Brazil, Croatia, Egypt, Greece, Hungary, Italy, Latvia, Lithuania, Netherlands, Poland, Portugal, Romania, Serbia, Slovenia and the United States of America). The number of valid responses received was 11,919 participants. The data were treated using SPSS software, and the main statistical techniques used included exploratory factor analysis, evaluation of internal reliability through Cronbach's alpha, cluster analysis (hierarchical and k-means) and logistic regression. The results obtained showed two groups of people: low motivated and notably motivated consumers. The results showed high asymmetries between countries, with highest percentage of highly motivated consumers in Egypt and the lowest percentage of highly motivated in Portugal. It was further observed that consumers more influenced by commercial and marketing aspects (the notably motivated) tend to be women, young, single, less educated, less likely to be professionally active, and those who live mostly in rural or suburban areas. Less exercise and overweight are also factors associated with greater propensity for commercial and marketing motivations. Furthermore, health problems such as shellfish or gluten intolerance, hypertension and high cholesterol confer less propensity to be in the segment of the notably motivated consumers. In conclusion, this work highlighted the role of geographic, sociodemographic and lifestyle factors as food choice determinants.

Keywords: marketing segmentation; food consumption; eating motivation; cluster analysis

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1. Introduction

Dietary patterns are greatly influenced by several kinds of motivations, including the interaction between individual factors with the external food environments that surround consumers. Among the individual factors for example are personal preferences, long time habits, health motivations or limitations, income and affordability, etc. (Bacârea et al., 2021; Bartkiene et al., 2019; Downs et al., 2022). On the other hand there are aspects such as the external food environment, which encompasses aspects such as the availability, convenience, marketing campaigns, promotions, quality, or even sustainability of the foods or food supply chains (Downs et al., 2020). It is also known that the sociocultural environment and political influences help shape consumer patterns in general, which is also applicable to the food choices (Turner et al., 2018).

Food advertising campaigns are responsible for part of the food market, since they directly influence consumers to buy certain types of food (Silva et al., 2021). Additionally, these marketing strategies are often directed to foods that are convenient, easy to consume, tasty, high in fat, sugar and salt, energy dense and very caloric but with a poor nutritional value (Carbonneau et al., 2021; Jiménez-Morales & Montaña Blasco, 2021; Martínez-Pastor et al., 2021). As a consequence, people tend to consume foods that are easy to purchase and cheap, but that contribute to the onset of many non-communicable diseases, leading to high social burdens also associated with obesity and related pathologies, like diabetes, high cholesterol, cardiovascular diseases and heart problems (Batschauer et al., 2020; Feriani et al., 2021; Lin et al., 2014; Loreto et al., 2021; Pan et al., 2021; Siu et al., 2007).

The advertisements focused on food products and beverages have proven to affect consumers' preferences, purchasing choices, and consumption patterns, also overlapping and/or influencing nutrition knowledge. To this matter, marketing campaigns on television in particular, have been promoting less healthy products (Cairns et al., 2013; Meiksin et al., 2021; Smith et al., 2019). However, in many countries some regulation has been implemented in order to restrict some types of advertisements of less healthy foods and incentive campaigns that

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drive consumers to healthier food choices (Thompson et al., 2021). Many of these strategies address specifically the children, as a way to promote long-time effects and achieve a better public health in the future generations (Carters-White et al., 2021; Mehta & Bharadwaj, 2021; von Nordheim et al., 2022).

Attending to the effect of marketing strategies and/or advertising campaigns on consumer's patterns and considering that people shape their food behaviours under the influence of so many different factors, including social, cultural and political aspects that vary among countries, this study aimed to investigate the peoples' eating motivations in a set of different countries, particularly in what comes to commercial and marketing influences on their food choices. Additionally, it was intended to understand how the people's personal characteristics are related to the way they shape their food choices and if they are influenced by commercial or marketing factors.

2. Methodology

This research was part of the EATMOT project and the data collection was assessed using the questionnaire developed and validated for that purpose as described in the work by Ferrão et al. (2019). All ethical principles were strictly guaranteed in the design and application of the questionnaire, which was approved by the Ethical Committee (Reference Nº 04/2017) before the data collection, which took place between September 2017 and June 2018. The participation was voluntary and included only adult citizens. All answers were kept anonymous and no personal data were collected to possibly relate to the answers, so as to protect the participants' anonymity. The questionnaire survey was distributed online to residents in sixteen countries spread along different parts of the globe, mostly Europe, but also America and Africa. The participating countries were: Argentina, Brazil, Croatia, Egypt, Greece, Hungary, Italy, Latvia, Lithuania, Netherlands, Poland, Portugal, Romania, Serbia, Slovenia and United States of America.

In addition to sociodemographic data, the questionnaire covered questions intended to characterize the respondents regarding anthropometric, behavioural and health related elements. This study focuses on commercial and marketing motivations related to food choices. Seven items were considered to measure marketing and commercials motivations. A five-point Likert-type scale was used, ranging from "Strongly disagree" to "Strongly agree" (Likert, 1932). The responses for two items were inverted so that higher scores consistently reflect higher level of commercial and marketing motivation.

Table 1. Commercial and marketing motivations for food choices

Code	Items for the Commercial and Marketing Motivations
M1	When I buy food I usually do not care about the marketing campaigns happening in the shop (Inverted)
M2	I eat what I eat, because I recognize it from advertisements or have seen it on TV
M3	I usually buy food that spontaneously appeals to me (e.g. situated at eye level, appealing colours, pleasant packaging)
M4	When I go shopping I prefer to read food labels instead of believing in advertising campaigns (Inverted)
M5	Food advertising campaigns increase my desire to eat certain foods
M6	Brands are important to me when making food choices
M7	I try to schedule my food shopping for when I know there are promotions or discounts

An exploratory factor analysis was applied to these items, by country, and the results were compared, in order to verify whether it would be possible to find a factor structure common to all countries. Three items were consistently aggregated in one factor for all countries, being then considered to define the factor "Advertising". Cronbach´s alpha was used to assess reliability. The other items were studied individually. As a result of this analysis, five variables were considered to measure marketing and commercials motivations: Advertising, Brands, Promotions/Discounts, Marketing Campaigns and Advertising over Labels. Cluster analysis was applied to identify consumer segments based on these five motivation variables. Three hierarchical techniques were applied, Ward's method, single linkage and average linkage, whose solutions were considered as initial solutions for the k-means method. This approach of starting k-means from a solution given by an hierarchical method is often

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recommended to obtain more accurate solutions (Hair et al., 2010). Additionally, the k-means method was applied to 50 bootstrap samples and the similarity of cluster solutions for different numbers of clusters was examined using the rand index (Dolnicar & Leisch, 2009). The rand index is a frequently used measure of agreement between cluster solutions, ranging from zero (none agreement) to one (total agreement). The two-group solution was found to be the most stable, with values of the rand index very close to its maximum value. Furthermore, the stability of the two-group solution was sustained by verifying that the solutions that emerged from the K-means after hierarchical methodology were fully co-incident (Hair et al., 2010). The two clusters separate respondents more motivated by commercial and marketing aspects from those less motivated. In order to characterize consumers with higher levels of commercial and marketing motivations, these two groups were then compared in relation to demographic, anthropometric, behavioural and health-related variables. Chi-square test and Mann-Whitney test were applied to make a first identification of the variables that differentiate the most motivated consumers. Logistic regression modelling was then used to identify the variables independently associated with higher levels of commercial and marketing motivations. Variables were chosen to enter in the model selection procedure if $p<0.1$. Friedman´s ANOVA and multiple comparisons by Bonferroni adjustment were applied to compare levels of the five motivational variables. Statistical analyses were performed using R package flexclust (Leisch, 2006; R Core Team, 2020) and IBM SPSS statistics (version 26). Significance was established for $p<0.05$.

3. Results

3.1. Demographic Characteristics of the Sample

The sample includes responses of 11,919 consumers from sixteen countries. Croatia and Portugal accounted for 12.9% and 11% of the sample, respectively, followed by Slovenia and United States of America (9.2 and 7.5%, respectively). The remainder countries represented less than 7% of the sample (Table 2). The female gender is more represented in the sample, comprising 71.4% of the respondents. The mean age is 34, with a standard deviation of 13.9 years old. Moreover, half of the participants were less than 31 years old and 34% ranged between 31 and 50 years. In terms of Education, the majority (61.1%) had a university degree. Most of the respondents were living in an urban environment (66.9%), 16.8% in a suburban area and 16.3% in a rural zone. Also, 47.5% was married or living together and 46% were single.

Table 2. Countries represented in the sample

Country	Frequency	Percent
Croatia	1538	12.9
Portugal	1314	11.0
Slovenia	1092	9.2
United States of America (USA)	890	7.5
Romania	821	6.9
Egypt	790	6.6
Brazil	665	5.6
Latvia	636	5.3
Poland	586	4.9
Italy	541	4.5
Argentina	522	4.4
Netherlands	521	4.4
Lithuania	507	4.3
Hungary	500	4.2
Greece	498	4.2
Serbia	498	4.2
Total	**11919**	**100**

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3.2. Segmentation by Commercial and Marketing Motivations

The seven items used to measure commercial and marketing motivations were subjected to an exploratory factor analysis by country. The three following items were consistently combined in one factor for all countries. The mean of these items was thus considered to define the factor called Advertisement.

- M2. I eat what I eat, because I recognize it from advertisements or have seen it on TV
- M3. I usually buy food that spontaneously appeals to me (e.g. situated at eye level, appealing colours, pleasant packaging)
- M5. Food advertising campaigns increase my desire to eat certain foods

The reliability of the scale is supported by Cronbach's alpha values which are not less than 0.6 (Table 3) in an analysis for each country, and equal to 0.7 in a global analysis with all data. Indeed, the general agreed upon lower limit for Cronbach´s alpha is 0.7, but this may decrease to 0.6 in an exploratory research (Hair et al., 2010).

Table 3. Cronbach´s alpha

Country	Argentina	Brazil	Croatia	Egypt	Greece	Hungary	Italy	Latvia
Cronbach's α	0.6	0.7	0.7	0.6	0.7	0.8	0.7	0.7
Country	Lithuania	Netherlands	Poland	Portugal	Romania	Serbia	Slovenia	USA
Cronbach's α	0.6	0.6	0.7	0.9	0.7	0.7	0.6	0.7

Regarding the other items, a common factor structure was not found in all countries and, therefore, they were studied separately. This study thus considers five variables to measure commercial and marketing motivations: Advertising (average of M2, M3 and M5), Brands (M6), Promotions/Discounts (M7), Marketing Campaigns (M1 – Inverted) and Advertising over Labels (M4 – Inverted).

As presented in Table 4, participants are more motivated by Brands and Promotions/Discounts, and then by Marketing Campaigns and Advertising, with significant differences between them all ($p<0.005$ for al pairwise comparisons). Yet, none of the five motivational variables had a mean value above 3.5, meaning that, in general, consumers exhibited medium and low commercial and marketing motivations.

Table 4. Mean and Standard Deviation of Commercial and Marketing Motivations

	Mean	Standard Deviation
Advertising	2.51	0.86
Brands	**3.07**	1.09
Promotions/Discounts	**3.00**	1.07
Marketing Campaigns	2.74	1.09
Advertising over labels	2.25	1.04

Although the motivational level for commercial and marketing aspects is not pronounced, it is still interesting to understand which consumers are most motivated by them. In this study, the main research problem lies in the following question: Overall, what makes consumers more prone to commercial and marketing motivations?
Applying cluster analysis, it was possible to identify two groups that were distinguished precisely by the level of commercial and marketing motivations:

- Notably motivated consumers – which covers 57.8% of the sample and is characterized as a group of consumers with higher levels of commercial and marketing motivations, since in the 5 motivational variables the means for this group are above the global mean.

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- Low motivated consumers – which includes 42.2% of respondents, those with lower levels of motivation as they present mean levels of motivation below the mean values for the entire sample.

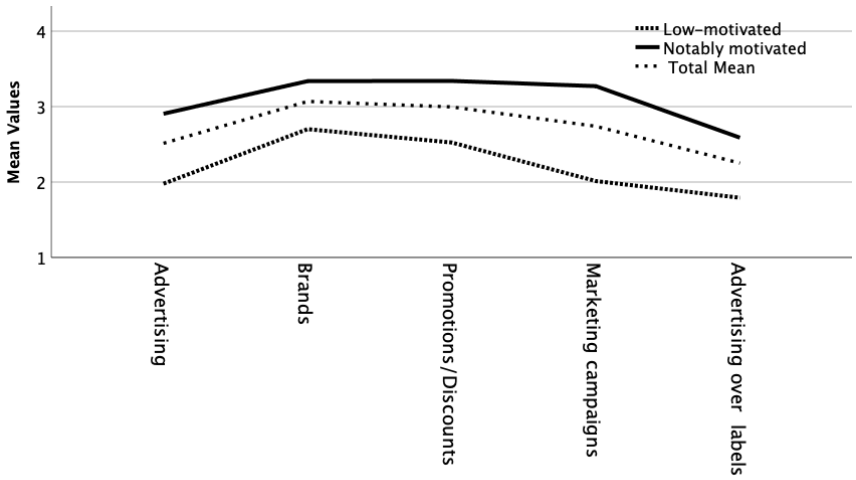

Figure 1. Average values of the five motivational variables for the entire sample and for the two groups

Clustering algorithms always provide a clustering solution regardless of whether or not a cluster structure exists in the dataset. If natural clusters exist in de data, they will emerge repeatedly over different computations. So, in cluster analysis, it is fundamental to assess the stability of a cluster solution in order to establish its validity (Hair et al., 2010). The two-group solution found in this study revealed good stability in the performed analysis, which supports its validity. In fact, when applying k-means to 50 bootstrap samples (Dolnicar & Leisch, 2009), the various clustering solutions found for the two-group solution were very similar, as indicated by the rand index, contrasting with solutions with another number of groups (Figure 2). Additionally, applying the K-means after hierarchical methodology, the three solutions obtained were fully co-incident, which further supports the stability of the two-cluster solution.

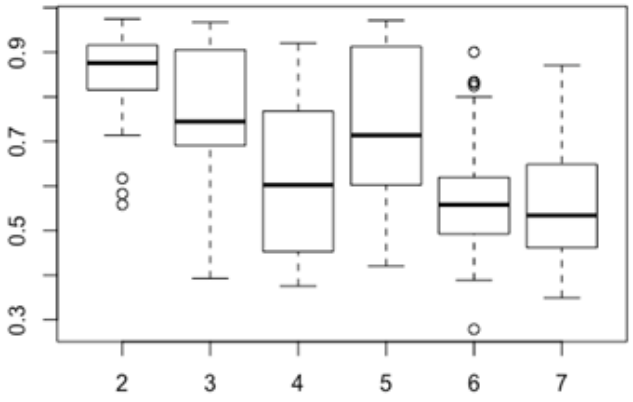

Figure 2. Similarity of cluster solutions for k number of clusters (k=2,3,…7)

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3.3. Cluster Profiles

To better understand the profile of consumers most prone to commercial and marketing motivations, the two groups were compared regarding demographic, anthropometric, behavioral and health related variables. Let us classify by group 1 the notably motivated consumers and group 2 the group of low motivated consumers.
When comparing the demographic characteristics of these two groups using univariate statistical analysis, significant differences are found (Table 5). Individuals belonging to the group of the most motivated tend to be younger than those in the group with less motivation (mean age group 1 = 32.7 years vs. mean age group 2 = 36.7 years, $p<0.005$). The notably motivated group has a higher percentage of women (72.2% vs. 70.2%), a higher percentage of single individuals (51.9% vs. 37.9%), a lower proportion of individuals with university education (58.3% vs. 66.1%), more consumers living in rural or suburban areas (37.2% vs. 27.6%), and more consumers who do not have an active professional activity, that is, unemployed, non-working students or retired (43.1% vs.31.1%).

Table 5. Cluster profiles: demographic characteristics

Variables/groups		**Low motivated Consumers (%)**	**Notably motivated Consumers (%)**	**Total (%)**	**p-value Chi-square**
Gender	Male	29.8	27.8	28.6	0.016
	Female	70.2	72.2	71.4	
Education Level	Primary School	1.1	2.9	2.1	<0.005
	Secondary School	32.8	38.8	36.3	
	University	66.1	58.3	61.6	
Living Environment	Rural	13.1	18.6	16.3	<0.005
	Suburban	14.5	18.6	16.8	
	Urban	72.4	62.9	66.9	
Civil State	Single	37.9	51.9	46.0	<0.005
	Married/Living together	54.0	42.7	47.5	
	Divorced/Separated	5.7	3.9	4.7	
	Widowed	2.3	1.5	1.9	
Professionally Active	Yes (employed or working student)	68.9	56.9	62.0	<0.005
	No (unemployed, non-working student or retired)	31.1	43.1	38.0	

Higher percentages of notably-motivated consumers are found in Egypt, Lithuania, Netherlands, Croatia and United States of America, with over 60% of respondents belonging to this segment. In contrast, Portugal, Poland Romania and Italy have less than 50% of notably motivated respondents (Figure 3).

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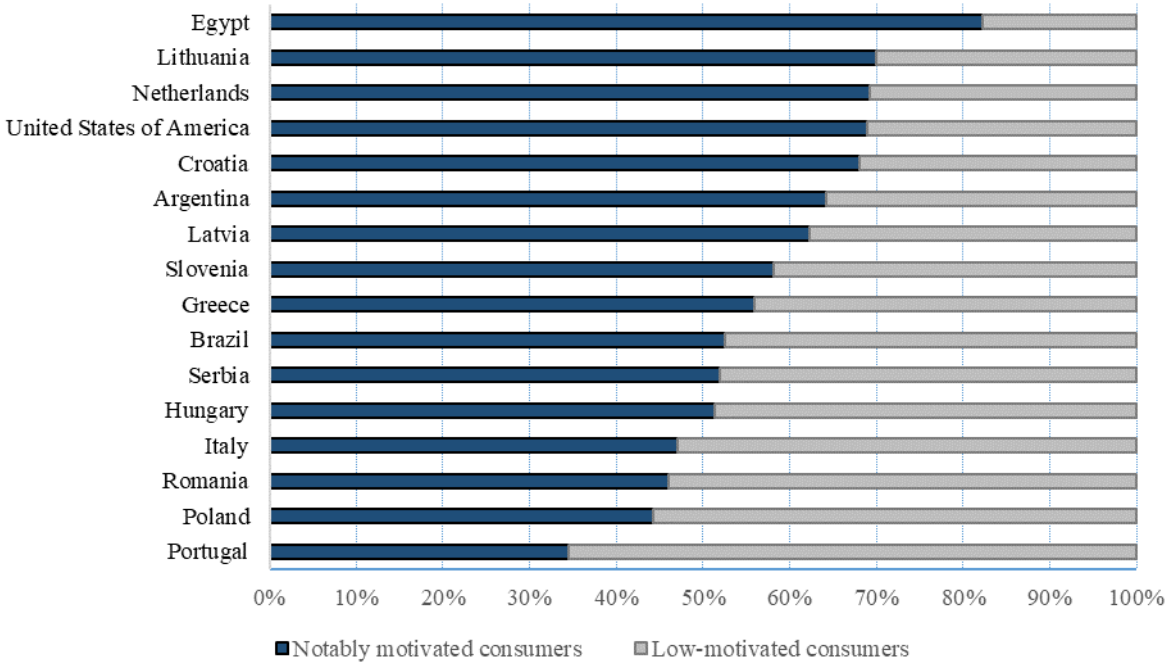

Figure 3. Cluster Profiles by Country

The group with greater motivation for commercial and marketing aspects has a higher percentage of consumers who do not exercise regularly (62.7% vs. 50.4, p<0.005). Accordingly, this is the group with the highest percentage of overweight or obese individuals (37.6% vs. 31.2%, p<0.005). There are no statistically significant differences between the two groups in the proportion of consumers with lactose (p=0.057), casein (p=0.87) or nuts (p=0.70) intolerance, or with associated diseases such as diabetes (p=0.768), intestinal disorders (p=0.346) and cardiovascular diseases (p=0.359). However, in the group of the most motivated there is a lower percentage of consumers with high cholesterol (4.0% vs. 7.0%, p<0.005), hypertension (5.5% vs. 9.2%, p<0.005) and gluten or shellfish intolerance (1.3% vs.2.1%, p=0.001 and 1.6% vs. 3.2%, p<0.005 respectively), but a higher percentage of consumers with gastric disorders (4.6% vs.3.4%, p<0.002).

Multivariate Logistic regression was used to estimate the odds of a consumer being in the notably motivated group, identifying the variables independently associated with higher levels of commercial and marketing motivations. The chances of belonging to the notably motivated group are higher for females (OR gender= 1.15, p=0.001) and decrease with age (OR age=0.99, p<0.005). As academic background increases, the odds of belonging to the notably motivated group decreases (OR secondary school=0.38, OR university=0.35, compared to primary school education level, p<0.005). It is in the rural environment that the most motivated are found: as we get closer to the urban environment, chance of belonging to the notably motivated group decreases (OR Suburban=1.23, OR Rural=1.32, comparing with the inhabitants of the urban environment, p<0.005). The chance of belonging to the motivated group increases with the grow in BMI (OR=1.06, p<0.005), is higher for people who are not professionally active (OR=1.23, p<0.005) and do not exercise much (OR occasionally=0.85, p=0.002, OR moderate/intensively=0.61, p<0.005, compared to the group that never/sporadically engages in physical exercise). Consumers with shellfish intolerance, gluten intolerance, arterial hypertension, high cholesterol are less likely to belong to the high motivation group and, in contrast, those with gastric disorders are more likely to belong to this group (Table 6).

Table 6. Logistic regression model: independent predictors of notably motivated consumers

	B	OR	Sig.	95% C.I.	
Age	-0.014	0.986	0.000	0.982	0.990
BMI	0.055	1.056	0.000	1.046	1.067
Gender=Female	0.143	1.154	0.001	1.058	1.259
Education Level					
Secondary School (compared to primary school)	-0.968	0.380	0.000	0.276	0.523
University (compared to primary school)	-1.062	0.346	0.000	0.252	0.475
Living environment					
Suburban (compared to Urban)	0.206	1.229	0.000	1.100	1.373
Rural (compared to Urban)	0.276	1.317	0.000	1.185	1.465
Civil State					
Married/living together (compared to single)	-0.286	0.752	0.000	0.680	0.831
Divorced/separated (compared to single)	-0.284	0.753	0.005	0.617	0.919
Widow (compared to single)	-0.308	0.735	0.055	0.536	1.007
Present professional activity = Not active	0.204	1.226	0.000	1,119	1.344
Physical Exercise					
Occasionally (compared to Never/Sporadically)	-0.166	0.847	0.002	0.763	0.940
Moderately /Intensively (compared to Never/Sporadically)	-0.496	0.609	0.000	0.557	0.665
High cholesterol = Present	-0.237	0.789	0.011	0.658	0.946
Arterial hypertension = Present	-0.269	0.764	0.001	0.648	0.901
Gastric disorders = Present	0.265	1.303	0.009	1.068	1,590
Gluten Intolerance= Present	-0.514	0.598	0.001	0.440	0.812
Shellfish Intolerance = Present	-0.563	0.569	0.000	0.436	0.743

4. Discussion

The results of the present work highlighted important dissimilarities between consumers from different countries in what concerns their shaping of food choices according to factors related to commercials and marketing. While consumers in Egypt, Lithuania, The Netherlands, United States or Croatia majorly in the group of notably motivated consumers, in contrast, Portuguese consumers are mostly in the category of low motivated consumers. The sociocultural environment and political regulations or public health strategies vary considerably among countries, and therefore it is expected that the behaviours of consumers are partly influenced by those factors (Dai et al., 2021; Rempe et al., 2019). Besides, a historical context attributes to food a diversity of functions, promoting social transformation and organization, geopolitical collaboration or competition, as well as industrial and economic development. Hence it acts as a reflection of the sociocultural interactions within a group, and countries, most of the times, represent different groups, to this purpose, given a common socio-cultural-political environment. Within most cultures, collective food consumption behaviours can be contextualized and better understood taking into account that each society constructs their own culturally-specific profiles (Hughes et al., 2017; Nunes et al., 2020; Standage, 2009; Stovall et al., 2021). Studies about the food marketing and advertising campaigns and their effects worldwide have shown differences. For example, Vanderlee et al. (2021) from the International Food Policy Study, reported differences between food marketing via television and digital media in five countries (Canada, United States, United Kingdom, Australia, and Mexico). These differences can naturally have some influence in the food choices of the citizens from different countries.

This study also found evidence that sociodemographic factors like age, education, marital status, living environment or professional activity influence the food choices. In particular, it was observed that consumers who are more prone to commercial and marketing motivations tend to be younger, less educated, are more likely to live in rural or suburban areas and less likely to be professionally active. Women and singles are also more likely

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to be part of the notably motivated consumers. Sociodemographic characteristics, have been associated with different food consumption patterns (Guiné, et al., 2020). According to the work by Dana et al. (2021) price was one of the dominant factors for food choice together with convenience, and segmentation was driven by demographic characteristics, particularly by age, gender and residential location. In another work by Marsola et al. (2022) identified some factors that determine food choice among Brazilian adults, which include, among others, price, easiness of preparation and buying convenience. Westenhoefer (2005) suggest age and gender as major factors influencing food choice, but also describe lifestyle and socio-economic situation as important drivers of food choice. In fact, the economic availability may have a decisive influence in buying intentions, and therefore the search for promotional campaigns or sales at lower prices are in people's minds when going shopping. In a study conducted in different countries, variables age, marital status, country, living environment, level of education and professional area were identified as significantly influencing the eating motivations, including those related with commercials and marketing of food items (Guiné et al., 2020).

Finally, it was also observed that lifestyle factors and health characteristics, such as physical exercise, body weight or health problems (allergies, hypertension, high cholesterol) are related to the consumer's behaviour in what concerns the commercial and marketing motivations. Less exercise and overweight are also factors associated with greater propensity for commercial and marketing motivations. Furthermore, health problems such as shellfish or gluten intolerance, hypertension and high cholesterol confer less propensity to be in the segment of the most motivated. But, in contrast, gastric disorders are associated with higher probability of being commercial/marketing motivated. Bacarêa et al. (2021) reported that age and presence of cardiovascular disorders were factors strongly influencing food choices. Also Wongprawmas et al. (2021) described the role of environmental aspects and health condition in the food choice and buying intention. People with excessive weight, who practise physical exercise or have certain health conditions are expected to play more attention to their diets, and therefore might be more motivated to escape the influences of commercials or marketing campaigns, especially those announcing non-healthy foods, like sugar dense, high fat (particularly saturated fat), high salt or excessively caloric but with a poor nutritional value (Banovic et al., 2021; Fox et al., 2021; Mesler et al., 2021).

Conclusions

This study produced some light into the characteristics of consumers that are related with their prone to be more or less influenced by food advertising and marketing strategies, in different sociocultural contexts.
Regarding the differences among countries, it was found that consumers in Egypt, Lithuania, The Netherlands, United States or Croatia are more prone to be in the group of notably motivated consumers in what concerns the economic and marketing motivations for food choice while in Portugal the highest percentage of consumers fall into the category of low motivated consumers.

The results further evidenced that consumers who are more prone to be influenced by commercial and marketing motivations tend to be younger, less educated, more likely to live in rural or suburban areas and less likely to be professionally active. Furthermore, women and singles are also among the groups more likely to be part of the notably motivated consumers. Additionally, the results showed that less exercise and overweight are also factors associated with greater propensity for commercial and marketing motivations.

Apart from the sociodemographic characteristics of the participants, also their health-related conditions were found to be associated with their food consumption motivations. For example, health problems such as shellfish or gluten intolerance, hypertension and high cholesterol confer less propensity to be in the segment of the most motivated consumers, which means that these are least influenced by commercial and marketing factors when making food purchases. In contrast, gastric disorders are associated with higher probability of being commercial/marketing motivated.

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ANALYSIS OF THE CRITICAL INFRASTRUCTURE CYBER SECURITY POLICY

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Abstract. Critical infrastructures are complex operating environments that often require special protection and security. A successful security strategy design should adhere to the principles of durability, integrity, and regularity. In the European Union, there is a strong interest in the security of critical infrastructures, especially those with interdependence. Given the fact that critical infrastructures play an essential role in a country's economy, it makes them even more vulnerable. The main aim of this article is to analyze the critical infrastructures' cyber security policy. The creation of a security strategy requires identification of the needs for equipment, mode of operation, and required security level. It has to establish rules for precise operation and handling of situations. The article tackles the issues of security strategy for critical infrastructures to protect sensitive areas and sectors. In addition, a cybersecurity policy as a countermeasure is discussed.

Keywords: industry; control systems; security; privacy; attack; management; energy

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JEL Classifications: O38

1. Introduction

Critical industrial infrastructures are under the name of critical because of their specificity in terms of the products and materials they produce (Brucherseifer et al., 2021). Critical infrastructures play a crucial role in a country's economy and actively contribute to the country's development by making the country more competitive. Critical infrastructures embrace information systems, industrial constructions, telecommunication networks, energy infrastructure, etc. The critical infrastructures are, as a rule, interdependent (Blokus, Dziula, 2019; Lin, Tai, Kong, Soon, 2019). The upgrade of the industrial tools in each infrastructure varies across different countries and by type of infrastructure. Critical infrastructures apply the latest technological equipment, while others may still use older technology, and, maybe several years older equipment. The different architectures of systems and the age of

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some industrial production units sometimes create, depending on their configuration, a security hole in the infrastructure, something that should be identified, evaluated, and eliminated.

In critical infrastructures, there are industrial control systems (ICSs) which include the various types of control systems (such as the SCADA system). Here it has to be mentioned, that SCADA in some cases appears to be vulnerable too (Cifranic et al., 2020). Besides SCADA, there is the Distributed Control Systems (DCSs), and other types of control systems in critical infrastructure, such as the Programmable Logic Controllers (PLCs) found in all critical infrastructures.

Critical infrastructure industrial systems consist of interdependent control devices designed to produce an industrial product or perform a process. Critical infrastructure, by definition, includes industries and areas, both physical and virtual (Krutz, 2016; Dawson, Bacius, Vassilakos, 2021). Critical infrastructure systems can be configured to operate with **loops**, and there are two types of loops, namely, the **open-loop** and the **closed-loop**. In the open-loop, control systems and the output is controlled by the specified settings. In the closed-loop, control systems and the output affects the input in such a way as to maintain system performance at the desired levels. A critical infrastructure contains numerous control loops, human-machine interfaces (HMIs), and diagnostic and maintenance tools based on a range of protocols. Industrial control processes are commonly used to manage resources and materials.

Critical infrastructure industrial production systems have evolved by adding IT functionality to existing systems of limited capabilities through automation of control mechanisms. Recently, the complete control of the data is carried out using digital media, which has replaced analogous mechanical controls. This technological breakthrough brought in huge advances in industrial technology, thus, production increased, safety rules were tightened, operating costs were reduced, and smart devices were added to take to automated roles, an example is a **smart grid**. Undoubtedly, it's a huge technological breakthrough. Still, it has significantly increased the connectivity of these systems and the ability to connect to other critical infrastructures that may be located in different geographical areas. This carries within it an increased risk that some of these systems at some point will be susceptible to some degree to vulnerabilities, whether small or large, assessing the level of penetration into the system by exploiting the system from which an attacker would attack trying to breach a system of critical infrastructure (Plėta et al., 2020; Djenna, Harous, Saidouni, 2021). For example, the unexpected and unalarmed shutdown of one high-voltage power line in northern Ohio in 2004 resulted in up to two days of blackout to 50 million people, costing an estimated $6 billion and leading to 11 fatalities (Yao et al., 2020).

According to the above-mentioned, it implies a greater need for adaptability, durability, and safety. The Framework and the Reports are major steps towards a cyber-security national policy, they are restricted to those areas defined as critical infrastructure (Dawson, Bacius, Vassilakos, 2021). Critical infrastructure systems differ from IT systems, which means that a security policy that can be applied to an organization **cannot** be applied to critical infrastructures, but it can be used partially, as some key elements can be used in accordance with the creation of an individualized security policy of critical infrastructure systems. A general security policy **cannot** be applied to critical infrastructure, as detection and countermeasures differ significantly.

We should not forget that there are different risks and challenges in critical infrastructures that need different assessments and priorities (Coole, Corkill, Woodward, A. 2012; Gabrijelcic et al. 2022). A failure to implement a security policy can expose infrastructure to significant **internal and external** threats.

There is a separate strand of scientific literature and legal documents devoted to solving cyber security issues of critical infrastructure. Those sources could be conditionally grouped into the following sets embracing specific facets. One broad facet is related to risk assessment and threats (Bennett, 2018; Baig, Zeadally, 2019; Li, 2020). To that group, extreme events can be attributed (Urlainis et al. 2022). Some authors point to the wide range of

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vulnerabilities brought by the Internet of things, and the Internet (Djenna, Harous, Saidouni, 2021). The risk and threats facet embraces the behavior of people, working with critical infrastructure (Kovacevic, Putnik, Toskovic, 2020). Another broad facet of cyber security issues is related to applied economic and legal principles (Loiko et al., 2020; Weiss, Biermann, 2021) applied for the management of critical infrastructure. Legal principles are reflected in the wide range of standards and guidelines, which is under constant development (e.g. IEEE Standards 2013, NIST, 2014; NIST, 2018; ISACA, 2018; NERC, 2019; Electric Reliability Corporation, n.d.). All those facets of cyber security issues result in the state of cyber security, or its resilience (Cernan et al., 2020; Rod et al., 2020). There are attempts of scientists to systemize the factors affecting the cyber security of critical infrastructure by building a theoretical model, which could be ultimately allowed us to see a bigger picture (e.g. Limba et al., 2017).

Despite all mentioned attempts by scientists and practicians, there are still many unanswered questions related to the formulation of cyber security policy elements. This gap triggers a research aim to articulate more clearly security strategy and cybersecurity policy in this specific area.

Failure of a security policy, therefore, poses a significant risk to the health and safety of infrastructure, equipment, and people in the infrastructure environment, causing serious damage to infrastructure facilities and disrupting the production process, as well as financial losses, as much as this implies the defamation of the state and the failure of the government to secure critical infrastructure in the country where the infrastructure is located.

The systems used in industrial plants in critical infrastructures have surpassed the older architectures. They are based on widely available interconnection technologies such as low-cost Ethernet and Internet Protocol (IP) devices. New architectures and increased interconnection capabilities significantly increase the chances of intrusion and vulnerability, which must be taken into account while designing the security policy to be implemented in critical infrastructure. Evaluation and countermeasures should be in place to identify security holes on time and to eliminate them. The higher the level of automation based on low-cost Ethernet and Internet Protocol (IP) devices, the greater the need to secure these systems against cyber-attacks. As mentioned above, there are no ready-made solutions for the protection and security of critical infrastructure systems. Each infrastructure should be evaluated differently; in no case should evaluations and safety proposals be overlooked for lack of difficulty in resolving decisions. The implementation of new security solutions should be considered as given, which will be adapted exclusively to the working environment and operation of the critical infrastructure. Critical infrastructures carry out complex processes that are constantly and uninterruptedly conducted, any interruptions of which would have disastrous consequences that might even affect other critical infrastructures, i.e. it is an immediate reaction to the problem, except of course the planned interruptions. The continuous inspections of the operations in infrastructure ensure a high level of rawness and availability of resources. A malfunction due to resource unavailability is capable of affecting production. It should be noted that these systems are not typical computers. Tips such as restarting to free up resources are unacceptable due to the adverse effects, as some systems run in parallel with other systems, in the event of a system's failure directly affecting the parallel systems with the result that perform a non-functional and highly complex operation of the infrastructure.

Cyber Security will grow even more together with an increase of the challenges for the security of critical infrastructures. Securing the function of critical infrastructures has become a policy priority worldwide as the potential for disasters given disruptions have been accentuated (Sonesson, Johansson, Cedergren, 2021). On the other hand, it will increase the critical infrastructures created with new standards and implement smart operational solutions that need particular analysis and protection. Electricity generation and management infrastructures face the most significant challenges, as all operations and services in all countries worldwide are based on energy. In addition, energy management systems use automated smart devices to immediately detect problem areas and immediately inform the control center. Artificial intelligence may, of course, significantly improve the situation. This technology allows for impending threats, process controls, and smart devices to be controlled and tracked in

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real-time. Inspection robots can also be used alongside artificial intelligence. An inspection robot may inspect the equipment and take pictures according to a set schedule for creating logs that contain, precisely, the functions applied, event functions, equipment functions, and measurements. This article emphasizes the security of critical industrial infrastructure systems and countermeasures.

2. Security policy analysis of the critical infrastructure

Critical infrastructure security is not just a countermeasure (counterattacking the hacker), but more like prevention measures. A security policy should protect facilities, processes, systems, production units, staff, integrity, confidentiality, and availability of information stored or transmitted in electronic form. It must anticipate and prevent any attack aimed at altering or limiting the functionality of the critical infrastructure. Staying on the same note, the statistics of cyber security for the past five years show a growing trend in the number of cyber-attacks against the systems of critical infrastructure as well in the detection of vulnerabilities and the gaps in the security of such systems (Bruzgiene, Jurgilas, 2021) (Fig. 1).

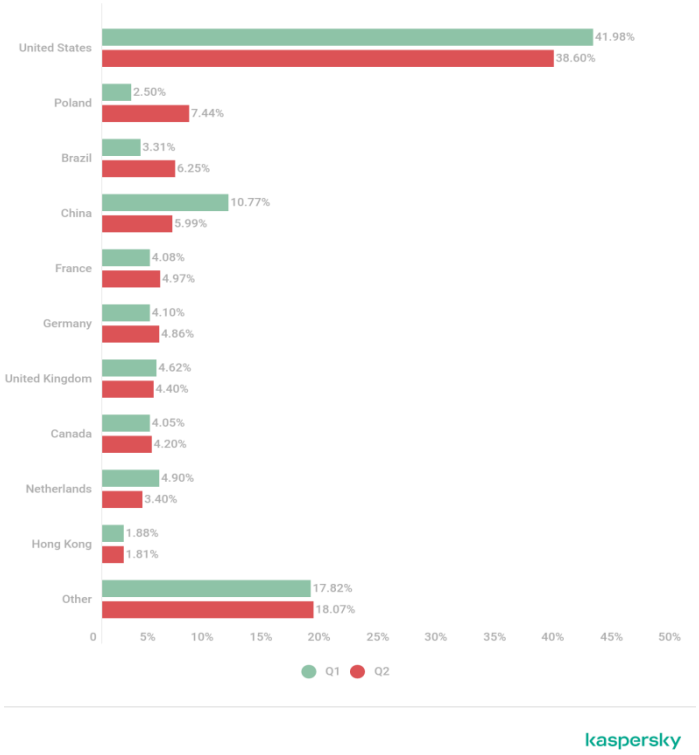

Fig. 1. Distribution of unique DDoS targets by country, Q1 and Q2 2021
Source: https://securelist.com/ddos-attacks-in-q2-2021/103424/

Creating an integrated security policy that offers realistic ways to detect, act, and respond to threats should take into account the following:

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- *The country's legislation is governed by the operation and management of infrastructure, taking into account all the parameters of the legislation.*

- *Noting the assets of critical infrastructure, such an action may include the cost of industrial equipment and reimbursement of the expenses in the event of partial or total destruction.*

- *The physical analysis of infrastructure facilities is significant in creating a security policy.*

- *Finally, the risk analysis throughout the infrastructure territory, evaluation, and analysis of all parameters that can directly or indirectly affect the operation of the infrastructure*

To implement the right countermeasures (not in terms of counterattacking the hacker), there must be a security policy that has taken into account all the infrastructure units which identify in detail the risks, the impacts, the security methods, the ways of reaction, the safeguarding of the infrastructure property, and finally, the security of the staff, i.e. the human factor.

The main predictors of policy success appear to be (a) the nature of the cyber threat to firms' operations and (b) regulatory pressure on firms (Atkins, Lawson, 2020).

However, to have a comprehensive security policy, and therefore a comprehensive protection and countermeasures plan, requires a detailed evaluation of the industrial equipment and systems, not in the form of a cumulative assessment, but rather in the form of an analysis of the equipment in relation to the operational level.

Evaluation at different levels of assessment evaluation at this level will go a long way in identifying both targeted proposals, draft measures, and countermeasures. Based on the above analysis, the security policy produced will include risk assessments, presentation of hazards and vulnerabilities, and the manner how these vulnerabilities affect the smooth operation of the infrastructure, as well as the extent and countermeasures used on a case-by-case basis.

The security policy required by every critical infrastructure is not common to all infrastructures; each critical infrastructure has different needs and vulnerabilities, diverse operating modes, and different industrial equipment. A security policy should differentiate at the level of risk all entities within the infrastructure by defining how one entity contains another and to what extent, for example, in the event of malfunction or attack. For this reason, the importance of detailed analysis of all units mentioned above, but in the form of equipment analysis in relation to the level of operation, i.e. evaluation at different levels of evaluation, should be included in the main body of security policy planning.

A security policy is built on the organization chart of the critical infrastructure. A security policy including security measures and countermeasures cannot change the organization chart, bypass, or ignore sectors and entities. A security policy should describe and define the methods of implementation, technical measures that identify technical issues, security measures and methods, the description and definition of the security method, the means of communication, and the way how this will be ensured at the critical moment to protect the staff who needs to be trained based on the security policy when the attack is organized under the predetermined instructions without overruns.

In conclusion, someone could say that the proper analysis, design, and implementation of a security policy, that will include multi-level analysis of all entities in conjunction with the control, detection, and analysis of

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vulnerabilities using models of forecasting future threats and defining the procedures and processes that will be adapted according to the circumstances, is a link for a very strong security policy.

The security policy of critical infrastructure is not a study that should be intimidating, the security policy should be reverently followed, and its purpose is to describe, identify, state the objectives, possible vulnerabilities, security methods, countermeasures, the description of staff responsibilities, and methods of communication and organization. In addition to the description of the above contents of the security policy, the security policy itself is an operating agreement between the management and the staff, thus, achieving the avoidance of each other at a critical moment, as it is a commitment between the two parties. In critical infrastructure, as in any organization, it is necessary to monitor the security policy to comply with it properly and to assign improvements or changes.

The organization chart of the critical infrastructure should indicate the security department which will be responsible for the evaluation, changes, management of the systems according to the safety rules as they are reflected in the security policy, the security issues that will arise, the security issues that concern the operation of the infrastructure, such as issues of coordination, supervision, communications, administration, problematic system configuration, continuous recording of security issues, staff training, and finally, reporting on the performance of security policy, and proposals for its revision.

A security policy defines the duties of each visionary and the degree of their involvement by describing their responsibilities. It should be made clear and understandable that security, especially in critical infrastructure, is not selective and does not allow discounts, security concerns all critical infrastructure staff, describing in detail their main responsibilities and tasks for each job existing in the infrastructure, and how they must comply with the security policy from the top executives as far as the ordinary employee. The human factor plays an important role in the faithful observance of security policy, security methods, and the implementation of countermeasures (not in terms of counterattacking the hacker). The reason is that within an infrastructure, there are employees of different grades, there are employees who work at critical points, other employees use automation that can be more vulnerable than another sector, there are also employees who, according to the organization chart, have low involvement, which means that if there is an attack they cannot and will not be involved to a large extent. The number of responsibilities is the one that involves employees more than others. As it is easily perceived that in case of danger, some employees will be more involved, this involvement can be crucial, as they will be able to deal with situations which in no case should lead them to panic. They should react collectively and methodically according to the training given to them. For this reason, the employees of infrastructure should be included in risk categories, the creation of risk rules will help significantly in their training, as the front line staff is the ones who will carry all the weight of the attack, so it is very important in zero time, to be organized and to make methodical moves of countermeasures, so that there would be no risk to the infrastructure, but not affecting a colleague who works at lower risk levels.

Unfortunately, the economic factor directly affects both the quality of the security policy and the security policy itself. Financial constraint is responsible for the lack of analysis of infrastructure entities and the adoption of appropriate security policies that will secure the infrastructure against attacks both in the medium and long term. The economic factor has a direct impact on the staff training, lack of training, risks to both staff health, and the smooth and safe operation of the infrastructure. Staff training on systems management, security measures, countermeasures shall be implemented on a case-by-case basis and emergency strategy formulation. All of the above entities are critical and are set aside due to economic factors. Typically, the above entities are included in the infrastructure budget and specifically by the security directorate or are partially included in other departments' budgets related to an entity.

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Laws and regulations should develop the security policy. At first glance, everything is quite simple, but the legislation changes frequently, technologies do not standstill. Therefore, it is necessary to respond on time to all innovations and changes.

As mentioned in this article, cybersecurity philosophy in critical infrastructure is rather prevention, and not countermeasures (counterattacking the hacker). Countermeasures come as a second solution and damage mitigation measures, on the other hand of a successful attack, which means lack of preventive security measures, which equates to the incomplete analysis of all entities, misjudgment, error, or non-implementation of proposed security policies. Studies have shown that the successful implementation of a security policy, that has been properly established by partially evaluating all critical infrastructures entity by entity, may secure the infrastructure against attacks. It is possible to prevent potential intrusions and intercept intrusion attempts. The method usually described in security policies is "**4D**" (**Deter, Detect, Delay, Detain or Defend**), while if the plan includes recovery methods and countermeasures, then add "**2R**" (**Respond, Recover**). From the initial stage of tracking down critical infrastructure, the information produced by the would-be attacker must be negligible, which means that the attacker finds an armored system that is reluctant to provide anyone with basic information such as its architecture or operating system versions. All these attempts made by would-be intruders should be logged in to the infrastructure security systems, analyzed by the security department, and evaluated based on existing measures if an existing policy can repel the intruder, and what is possible could be added or modified.

In 2019, warnings that cyber threats pose a risk to public welfare, security, and prosperity were published in the National Intelligence Strategy Report of the United States. Those warnings were related to the fact that information technologies are inseparable from critical infrastructures and are widely used by society (Bruzgiene, Jurgilas, 2021). Prospective intruders who persistently attempt to invade a critical infrastructure system, properly implement security policy, adhere to measures, and write the correct security policy are the ones who will determine the successful avoidance of intrusion into the systems. An emergency delay plan should always be available, and this plan should be divided into **two phases**. The **first phase** is when a significant volume attack has been carried out, for example, **DDoS (**Fig. 2**)**, which may be large and cannot be dealt with existing security systems, this requires the application of mitigation methods; the **second phase** is when there is a partial breach of a system and delay methods should be applied which will prevent further break-in of intruders into the systems, a solution would be to use **Iron Box** and direct the attacker towards it. Partial breach of the network and intrusion into critical infrastructure systems **are not acceptable**. The above methods of delay are **temporary, and emergency solutions as in no case should potential intruders reach this point**. The implementation of delay methods denotes a lack of policy on the one hand because it signifies a breach of systems. On the other hand, the start of the implementation of the delay methods is equivalent to a period that can be crucial both for the plans, the industrial equipment, and the staff, and their protection of health and safety. Usually, when such attacks occur, the adequacy of security measures is judged. Regardless of the definition, CI entities are exposed to various types of threats related to human activities, natural disasters, and military, terrorist, or cyberspace attacks. Therefore, the ability to identify and predict threats toward CI entities and the capability to indicate how to proceed when they occur is nowadays a common subject of many research initiatives (Wisniewsk, 2020). For example, output from a recent evaluation of the European critical infrastructure protection directive (CIP directive) and the suggested new approach for the European program for critical infrastructure protection (EPCIP) suggests taking a resilience perspective as a means to enable more focus on cross-sector interdependencies (Sonesson, Johansson, Cedergren 2021).

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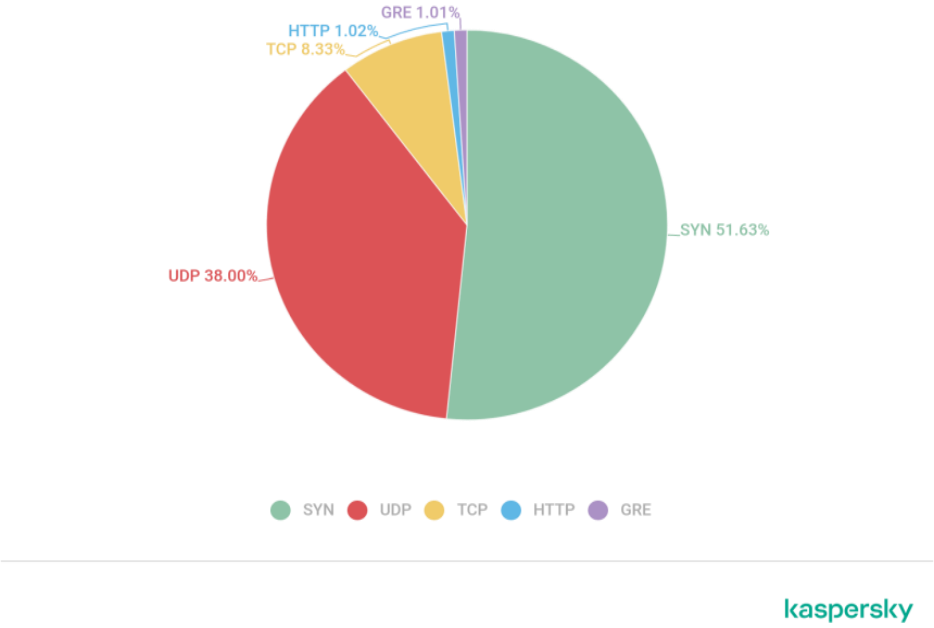

Fig. 2. Distribution of DDoS attacks by type, Q3 2021
Source: https://securelist.com/ddos-attacks-in-q3-2021/104796/

3. Methodology of security policy

The implemented critical infrastructure security policy, as mentioned in this article, should evaluate each sector as an entity, which means that the evaluation should not be uniform for all, it should take into account the criticality of each sector, it should implement the **layout policy of the six sectors** according to their criticality, as described below.

- **Sector 1:** *Security of the Perimeter of Critical Infrastructure.*
- **Sector 2**: *Indoor / Outdoor Entries.*
- **Sector 3**: *Shared Areas Within the Critical Infrastructure.*
- **Sector 4:** *Office Areas.*
- **Sector 5:** *Critical Industrial Sector / Systems Control.*
- **Sector 6:** *Very Critical Industrial Sector / Systems Control.*

Implementing security sectors in a security policy is very important because each industry has different security requirements. Besides, there is the possibility of implementing robust security policies between the sectors, especially the critical and very critical sectors. We should not overlook the fact that critical infrastructures are very expensive, and choosing the cost of the damage would be huge because those parts that have been damaged will have to be repaired or replaced. In addition, the social cost is huge as services, such as energy or fuel, will not

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be provided to citizens. Power infrastructures are expensive to procure and complicated in their installation, hence, requires a comprehensive security provision for every potential threat, which could fail any unit, system or even cause cascade effects across the infrastructure (Abdulrahaman, Mohd, Raja, 2018).

Each of the above six sectors should form a safety belt that will be properly configured depending on the level of danger. Each industry will consist of complex security measures that include a combination of technical elements that will determine the seriousness of the sector they are applied to. In case of delay, rules will not involve the industry's security. Technical overlaps are **not acceptable** in critical infrastructures as overlap means the inability to apply the correct security rules, and in addition, overlaps hide security vulnerabilities. It is very important to have a secure security policy, especially in the very critical sectors of the infrastructure, so as not to jeopardize the smooth operation of the infrastructure. Nevertheless, to achieve security policy awareness effectively, it is necessary to use rich but compelling textual and visual material (Faizan, Dominic, Kashif, 2020). An important sector that needs high security is the control center, ranked as **sector 6**, which requires special attention and protection, from this point the controls are carried out in the industrial units of the infrastructure, a lack of security policy which would not taken into account security vulnerabilities, and implementation flaws would have a truly devastating effect in the event of an attack.

The aforementioned **sectors 5 and 6** are the heart of the infrastructure, for this reason, they need increased special security, there must be identification and development of security procedures that will be clear and efficient taking into account the procedures carried out in each sector, the origin and mission processes, staff carrying out the procedures in these areas, the level of staff training, the actions that staff can perform, it should also be taken into account how security mechanisms, delays, and countermeasures will work, whether they will work partially and automatically, or the human factor will be involved, as well as the reaction time will have to be determined. Staff working in areas **5 and 6** should be in addition to well-trained staff but should be aware of procedures for using computer resources in order not to be wasted unnecessarily so that when free resources are needed, there are no available ones. Moreover, in these **two sensitive sectors**, staff who have been involved in delinquent behavior in the past, who do not know what constitutes confidential information or who have been involved in sharing sensitive information, or have previously been found to be involved in sabotage **should not** be placed.

External collaborators invited by critical infrastructure executives to carry out projects should fully comply with the security policy, as well as carry out the necessary assessments if the external collaborators meet the system management and security criteria, particularly in **sectors 5 and 6,** as to their ability to perform the task for which they were called upon without affecting the safety of the critical infrastructure. Proper implementation of security policies is a prerequisite for achieving the desired level of security and is largely obtained by the correct use of equipment, forecast models, and the immediate use of countermeasures, where required. The staff's implementation of the security policy in a situation that continuously performs its role is the responsibility of the staff who uses it. Both responsibilities and cross-sectoral cooperation must be clearly described in the emergency management process as in the event of an attack.

The application of the **ISA 95** standard in industrial production will immediately highlight its benefits as there are many tools provided and many automated tools available to the infrastructure users. Implementing ISA 95 will **reduce costs, risk, errors and significantly increase safety** by preventing errors related to the management of production control systems. ISA 95 is a part of a multi-sectoral set of standards that defines the interfaces between the control and industrial sectors. The template complies with **IEC** regulations, and its purpose is to:

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- *Defining control and construction fields.*
- *The organization of the data.*
- *Defining functions.*
- *The control interface with the functions of an infrastructure.*
- *Defining the information shared between systems.*

ISA 95 is an international standard for developing automated control systems interfaces developed by industrial system manufacturers and designed to be applied to the industry. The standard defines what information and with whom and which systems should interact. ISA 95 categorizes activities into categories defining the functions at the level of production, quality, maintenance, and inventory management. The human factor remains an important entity in critical infrastructure. Therefore, the human factor must be ranked within the infrastructure to distribute roles and responsibilities. Thus, an industrial unit should implement roles such as control, supervision, coordination, security, crisis management, response, incident collection, communication, and physical security. Hence, the roles are listed below.

- **Control team:** *Checks an industrial infrastructure whether it complies with operating standards and security, including proper process management, implementation of security measures, drafting security policy, Data recovery plan, conducting controls on infrastructure information systems, collection, and evaluation of security vulnerabilities, while any omissions are made in a report where they are then applied to the infrastructure.*
- **Supervision team:** *supervises the control team and all processes performed in an industrial unit. The team actively cooperates in departments for the industrial unit's smooth operation, elaborates studies and plans, sets safety standards, provides advice and practices, evaluates the criticality of systems, prepares improvement instructions, and plays an advisory role.*
- **Coordination Team:** *Hierarchically, receives and gives orders to other teams, works closely with the control team, collaborates with security and crisis management teams, and oversees overall operational management of the infrastructure.*
- **Security Team:** *is responsible for data security, information and process integrity, infrastructure upgrades, and security policies.*
- **Crisis Management Team:** *is responsible for the management and accountability of any crisis occurring within an infrastructure. It is responsible for crisis management, analyses the data up to now, supervises studies for future problems, and cooperates with the control team and the response team to neutralize any future threats.*
- **Response Team:** *consists of people who will face cyber-attacks and any other cyber threats that may damage the infrastructure. The team is also responsible for secure data recovery if needed.*
- **Incident Collection Team:** *operates as an incident logging center within the infrastructure. It collects the data, analyses it, and communicates it to the interested groups. In critical cases, it directly informs the competent group. Finally, it conducts statistical research of the requests.*

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- **Communication Team:** *is responsible for internal and external communications and undertakes to inform citizens and competent bodies about anything in an infrastructure.*

- **Physical Security Team:** *It is the team that naturally guards critical infrastructure.*

Preventing an attack remains the primary choice. The use of countermeasures could be acceptable in applying countermeasures to changing settings and services on infrastructure during an attack, but this should not be confused with choosing countermeasures back to hackers. For example, it **would not be accepted** in the event of a distributed DDS attack being deployed to critical infrastructure, then the critical infrastructure being attacked back in the same way to hackers.

Access (by physical or electronic means) to critical infrastructure installations is restricted to authorized users, processes, and devices by physical or electronic means. This requires appropriate "**Authentication**" mechanisms, and access control procedures. Systems and applications are installed, developed, and managed to take into account the security policy that must be fully complied with security requirements throughout their life cycle. The data necessary for essential services are protected from their possible loss by keeping backup copies in an appropriate format, which allows for their immediate recovery. For this purpose, applicable policies, procedures, and automated systems for making and maintaining back-ups mentioned in the security policy are applied. To ensure the resilience of the systems against threats, appropriate and proportionate security solutions are installed and used. In particular, technological solutions to detect, record, and analyze threats are encouraged to achieve a more realistic security policy against threats. The results of a successful attack can lead to huge financial costs, difficulty, the long time to return the industrial systems to operating conditions, the loss of secrets or national security information, etc. Cyberwarfare takes the form of an asymmetric war. It is, therefore, very difficult to locate the attackers and their source. It requires specialized and highly educated staff, and finally, while it requires relatively low cost, it brings huge financial consequences, for these reasons, the critical situation of a country should be obliged to implement the security policy which should be regularly updated using models of future threat forecasts.

Conclusions

This article was written to highlight the validity of the comprehensive and proper use of a security policy in critical infrastructures. The facts set out in this article were aimed at understanding how a security policy should determine both the elements of correct recording, forecasting, and countermeasures. Countermeasures do not mean counterattacking the attacker the same way the attacker attacked the infrastructure. On the one hand, the advancement of technology offers new security possibilities. On the other hand, modern computing power creates new applications with new opportunities that affect the infrastructure. This article emphasizes the need for the security of critical infrastructures to be divided into sectors, each sector having a different weight from the others, different needs, and different functions. By the method of division into sectors, the most detailed overhaul of the operational parts of the infrastructure is achieved, as well as the application of different enhanced security measures in critical industries that use critical industrial equipment about other sectors, such as the control center, provides operators with increased state awareness which translates into increased prevention or early detection of operational problems. When threats to critical infrastructure are rising, their security technology applications using sophisticated studies enable them to address threats in the best possible manner. The security policy of critical infrastructure should in no case be considered as a model that was designed and continues to be applied for years, especially in cases where it has not been tested in the form of an attack on critical infrastructure. The security policy should be reviewed regularly, including security measures, countermeasures, and user education. The evaluation of actions taken no later than six months after the initial or renewed version of the security policy should be extensively evaluated. The security policy should include instructions for reporting security

vulnerabilities detected by staff using the industrial systems. Finally, new research and proposals in the security policy of critical infrastructures can protect and improve security.

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ECONOMIC USEFULNESS OF OLDER WORKERS IN TERMS OF PRODUCTIVITY IN THE MODERN WORLD

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Abstract. Along with the modern phenomenon of population aging, economists are also concerned about a shift in the composition of the workforce from relatively young to relatively old workers. This study is aimed to empirically prove the hypothesis that in the modern world the economic usefulness of older workers in terms of productivity is determined, in addition to the characteristics of the elderly workforce, by factors characterizing the level of territory development. The theoretical background and methodology of this study is formed on the basis of the concept of "specific human capital" by G. Becker and the conception of endogenous growth. The author uses the latest statistics for 63 countries of the world and several methods of quantitative data analysis: correlation analysis, regression analysis and cluster analysis – in order to detect not only correlational parallelism, but also causal relationships between the variables included in the proof of the research hypothesis. The results of the empirical analysis show that technological readiness, along with a high level of lifelong learning in the country, are the catalysts that ensure the economic usefulness of older workers in terms of productivity in the countries of the modern world. The author also concludes that a baseless raising the retirement age in the country, without considering the above factors that characterize the level of development of this country in technological and learning aspects, does not allow the effective use of the economic potential of older workers.

Keywords: older workers; economic usefulness; productivity; specific human capital; endogenous growth

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JEL Classifications: I38, J11, J14

Additional disciplines: sociology

1. Introduction

Along with the modern phenomenon of population aging, economists are also concerned about a shift in the composition of the workforce from relatively young to relatively old workers, i.e. a phenomenon that the researchers refer to as "workforce aging" (Aiyar et al., 2016). In most industrialized countries, the average age of the workforce has been growing rapidly during the recent years (Gobel & Zwick, 2011), and the share of older workers in the European labor force is expected to increase substantially over the next few decades (Cataldi et al., 2011; Aiyar et al., 2016). In particular, in his previous research the author found that over the past 10 years, Latvia has a rapid – almost 2 times – increase in the elderly (65+) employment, which quantitatively corresponds to the general EU's trend (Kudins, 2021). In this regard, a discussion about the economic usefulness of older

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workers is relevant in the research space (Verhaegen & Salthouse, 1997; Colonia-Willner, 1998; Skirbekk, 2003; Gobel & Zwick, 2011; Projektu un kvalitates vadiba, 2014; Borsch-Supan & Weiss, 2016; Boring & Grogaard, 2021 and others).

On the one hand, in the scientific literature in the framework of ageism there are (and even prevail) opinions that point to the unjustified recognition of older workers as necessary for the economy due to their low productivity compared to younger workers (Avolio & Waldman, 1994; Kahana et al., 2018). The manifestation of ageism in a broader socio-economic context is considered as part of the theory of modernization at the macro-level. The essence of the argument is that ageism increases as societies modernize, but social policies and management practices that emerged with industrialization are being rolled back over the last decades (De Tavernier et al., 2019).

The results of many studies show that the knowledge, skills and experience of older people are underutilized in the economy (Gobel & Zwick, 2011; PwC Global, 2018; Connie, 2020). The New England Journal of Medicine published a study in 2018, reporting that an extensive study in the USA found that the most productive age in human life is between 60-70 years of age. The second most productive stage of the human being is from 70 to 80 years of age. The third most productive stage is 50 to 60 years of age (Connie, 2020). Ageism leads to poorer health, social isolation, earlier deaths and cost economies billions: WHO report "Ageism is a Global Challenge: UN" calls for swift action to implement effective anti-ageism strategies (World Health Organization, 2021).

In addition to the aforementioned extreme positions, there are also compromise positions in the scientific literature in relation to the economic usefulness of older workers in terms of productivity. For example, V. Skirbekk in his study based on a literature survey about age and individual productivity concluded that the decreased cognitive abilities of older workers can lead to lower productivity, unless their longer experience and higher levels of job knowledge outweighs the declines in mental abilities (Skirbekk, 2003). He also found that productivity reductions at older ages are particularly strong for work tasks where problem solving, learning and speed are needed, while in jobs where experience and verbal abilities are important, older individuals' maintain a relatively high productivity level (Skirbekk, 2003).

Furthermore, the results of some studies also point to spatial differences in the professional potential of people of different age groups. For example, the researchers P. Boring and J.B. Grogaard (2021) examined the relationship between employees' age and their individual productivity potential (IPP). IPP is measured by individual characteristics which are related to skills utilization at work. Using data of the Programme for the International Assessment of Adult Competencies (PIAAC) for 27 European and non-European countries, they found that the oldest employees have a lower IPP score than the middle-aged employees in 17 of the 27 countries (Boring & Grogaard, 2021). Based on the results of this study, the author hypothesizes that in the modern world, the economic usefulness of older workers in terms of productivity is determined, in addition to the characteristics of the elderly workforce, by factors characterizing the level of territory (country, region, etc.) development.

Within this study, productivity is a target function that depends (or does not depend, as the results of the study will show) on "workforce aging" (Aiyar et al., 2016). Productivity will be considered not at the individual level of workers, but at the macroeconomic level, i.e. at the level of productivity of the economy as a whole, as many regional economists do in their studies (Rice & Venables, 2004a, 2004b; Cusolito & Maloney, 2018; Komarova et al., 2021). Methodologically, the author will consider the macroeconomic aspect of productivity based on the theory of human capital, which emphasizes its impact both on economic growth as a whole (Romer, 1986, 1989a, 1989b; Barro, 2001; Becker, 1993, 2009; Pelinescu, 2015), and on the productivity of the economy and firms operating in it (Hellerstein & Neumark, 1995; Hellerstein et al., 1999; Abel et al., 2010; Cardoso & Guimaraes, 2010; Cocalia, 2015; Andretta et al., 2021).

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As sources of empirical data to prove the hypothesis of this study, the author uses the latest statistics from the World Health Organization, Trading Economics, PwC Global, as well as data from the report on the Global Talent Competitiveness Index for 63 countries representing different continents and different levels of economic development. However, the relatively small sample size and the lack of diachronic analysis are the main limitations of this study, reducing the stability of the results obtained. To compensate for the above limitations, the author uses several methods of quantitative data analysis: correlation analysis, regression analysis and cluster analysis – in order to detect not only correlational parallelism, but also causal relationships (Keim, 2020) between the analyzed variables.

2. Theoretical background

A large body of evidence supports the notion that cognitive abilities2 decline from some stage in adulthood. P. Verhaegen and T.A. Salthouse (1997) present a meta-analysis of 91 studies, which investigate how mental abilities develop over the life span. Based on the analysis of these studies, they conclude that the cognitive abilities reasoning, speed and episodic memory declines significantly before 50 years of age and more thereafter (Verhaegen & Salthouse, 1997). However, in relation to the productivity of older workers, some researchers emphasize that it is a widespread stereotype that older workers are probably less productive: "the arguments given in the literature are that the physical abilities decrease in general, cognitive abilities at least in some areas" (Barthel, 2008, p. 3).

An interesting sociological study of economic potential of the population of pre-retirement age was conducted by Latvian researchers (Projektu un kvalitates vadiba, 2014). They found that "older people believe that they have much more experience than younger people, but less skills in working with new technologies. Those older people who feel that they lack some kind of knowledge or skills most often cite computer skills, English proficiency and basic business knowledge as insufficient. In turn, employers also value the experience of older workers, their reliability and ability to make independent decisions. At the same time, abilities, skills and competencies such as openness to new ideas, working with new technologies and creativity, according to employers, are less common among workers aged 50 years and older compared to younger workers" (Projektu un kvalitates vadiba, 2014, p. 68).

Back in the 1960s, economists T. Schultz and G. Becker pointed out that education and training were investments that could add to productivity (Schultz, 1961; Becker, 1964). Later, throughout his life, G. Becker and his colleagues actively continued economic studies of human capital (Becker & Ghez, 1975; Becker, 1993, 2009; Becker et al. 2010). The most necessary for the methodology of this study is the separation of the concepts of "general human capital" and "specific human capital" proposed by G. Becker (the Recipient of the 1992 Nobel Prize in Economic Science) (Becker, 1993). In his opinion, the general human capital, as a rule, is developed by special "firms" (schools, colleges), and the special one is formed directly at the workplace. The term "specific human capital" has helped to understand why long-serving workers in the same job are less likely to change jobs, and why firms tend to fill vacancies through internal job travel rather than through external recruitment (Becker, 2009; Becker et al. 2010). Thus "specific human capital" by G. Becker accumulated over a long professional activity (and not even necessarily within one firm or organization, but on the labor market as a whole) can theoretically be considered a determinant of the economic usefulness of older workers in terms of productivity.

I.J. Deary with his colleagues provide an overview of surveys that focus on how age differences in productivity are estimated by employer-employee studies (Deary et al, 2000). They conclude that for 5 out of the 7 employer-employee studies, an inverted U-shaped work performance profile is found, where individuals in their 30s and 40s have the highest productivity levels. Employees above the age of 50 are found to have lower productivity than younger individuals, in spite of their higher wage levels. Exceptions to the notion of decreasing productivity is a notion by J.K. Hellerstein and D. Neumark who suggest that productivity increase over the life span in a study of

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Israeli manufacturing firms (Hellerstein & Neumark, 1995). Similarly, in a study of American firms, J.K. Hellerstein, D. Newmark and K. Troske suggest that those above 55 contribute the most to output levels. However, they find that the peak productivity shifts to 35-54-year-olds workers when they use the firms' value-added instead of output levels as an indicator of productivity (Hellerstein et al., 1999). A.R. Cardoso and P. Guimaraes using a panel of Portuguese private sector firms that spans for over 20 years find that older workers are, in fact, worthy of their pay, in the sense that their contribution to firm-level productivity exceeds their contribution to the wage bill (Cardoso & Guimaraes, 2010).

The mention of high-tech Israel, in which "productivity increase over the life span" (Hellerstein & Neumark, 1995, p. 110), as well as the United States and Portugal, suggests that in the modern world the economic usefulness of older workers in terms of productivity is determined, in addition to the characteristics of the elderly workforce, by factors characterizing the level of development of the country as such. And, most likely, these factors relate to the development of technology, lifelong learning, etc. In a special edition of the Global Competitiveness Report issued by the World Economic Forum in 2020, a very interesting indicator is calculated (unfortunately, only for 37 countries of the world) - transformation readiness, which includes 11 structural elements (the so-called transformation economic priorities), namely (Schwab et al., 2020):

1) ensure public institutions embed strong governance principles and a long-term vision and build trust by serving their citizens;
2) upgrade infrastructure to accelerate the energy transition and broaden access to electricity and ICT;
3) shift to more progressive taxation, rethinking how corporations, wealth and labour are taxed, nationally and in an international cooperative framework;
4) update education curricula and expand investment in the skills needed for jobs and "markets of tomorrow";
5) rethink labour laws and social protection for the new economy and the new needs of the workforce;
6) expand eldercare, childcare and healthcare infrastructure, access and innovation for the benefit of people and the economy;
7) increase incentives to direct financial resources towards long-term investments, strengthen stability and expand inclusion;
8) rethink competition and anti-trust frameworks needed in the Fourth Industrial Revolution, ensuring market access, both locally and internationally;
9) facilitate the creation of "markets of tomorrow", especially in areas that require public-private collaboration;
10) incentivize and expand patient investments in research, innovation and invention that can create new "markets of tomorrow";
11) incentivize firms to embrace diversity, equity and inclusion to enhance creativity.

These 11 emerging priorities are vital for countries' achieving economic transformation: "moving towards a full integration of social, environmental and institutional targets into their economic systems over the next five years (approximately). Transformation readiness of countries assesses the extent to which countries today are on the way towards transforming their economies" (Schwab et al., 2020, p. 44). In combination with other characteristics of countries (macroeconomic productivity, lifelong learning), as well as indicators characterizing workforce aging, results are obtained that do not yet prove, but testify in favor of the hypothesis of this study. In the following table, the author compares data on some indicators regarding the economic usefulness of older workers in terms of productivity in the countries with the highest and lowest scores of transformation readiness.

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Table 1. Some indicators regarding economic usefulness of older workers in terms of productivity in the countries with highest and lowest scores of transformation readiness

Countries	Transformation readiness, score from 0 to 100, 2020	Lifelong learning, score from 0 to 100, 2021	Productivity of the economy* – GDP per capita (PPP), thousands USD, 2020	Retirement age for men, years, 2020-2021	Men's average life duration after retirement, years, 2020	% of people aged 65+ in employment. 2016
5 countries with highest scores of transformation readiness						
Finland	69.9	71.4	51.1	63.8	15.5	14.1
Sweden	68.5	77.8	54.6	62.0	18,8	21.9
Denmark	66.5	70.6	60.4	66.5	13.1	15.3
China	65.5	83.4	17.3	60.0	14.7	No data
Canada	64.2	73.7	48.1	65.0	15.4	24.6
5 countries with lowest scores of transformation readiness						
India	49.5	36.5	6.5	60.0	9.5	No data
Poland	48.8	28.1	34.3	65.0	9.5	9.5
Hungary	48.1	37.6	33.1	64.5	8.6	4.6
Greece	47.2	24.2	28.5	67.0	11.6	7.9
Mexico	46.9	40.6	18.8	65.0	8.1	38.1

* In the scientific literature, productivity at the macroeconomic level is usually measured using gross domestic product (GDP) per capita (Rice & Venables, 2004a, 2004b; Cusolito & Maloney, 2018).

Source: elaborated by the author based on Lanvin & Monteiro, 2021; PwC Global, 2017; Trading Economics, 2022; World Health Organization, 2020; Schwab et al., 2020 (data set is provided in the Appendix).

As can be seen from the data in Table 1, the five countries with the highest scores of transformation readiness are quite different from the five countries with the lowest scores of transformation readiness, not only in terms of the indicator of transformation readiness itself, but also in all other indicators given in the table. Thus, in countries with the highest scores of transformation readiness, the indicators of lifelong learning, productivity of the economy, share of people aged 65+ in employment (with the exception of Mexico), men's average life duration after retirement (indicating the state of health of the retiring workforce) are also obviously higher. The only thing that is not higher in the five countries with highest scores of transformation readiness than in the five countries with lowest scores of transformation readiness is the retirement age for men (with a few exceptions - India with a relatively low retirement age and Denmark with Canada with relatively high retirement age). It seems that in the modern world, an increase in retirement age should also be accompanied by at least a high level of life expectancy in the country, as well as high rates of lifelong learning and transformation readiness - only then will older workers be able to be economically useful and increase the productivity of their country's economy.

Thus, based on the analysis of the relevant scientific literature, as well as some empirical data that allow us to understand something about the economic usefulness of older workers in terms of productivity, the author believes that in the modern world the situation with the economic usefulness of older workers is ambiguous. Most likely, for the most complete economic implementation of the so-called "specific human capital" of older workers, some more educational and technological conditions are required, and not just an increase in retirement age while maintaining a relatively low life expectancy of the population and the transformation potential of the country. Further, the author will try to empirically prove this on a sample of 63 countries of the world using several methods of quantitative data analysis at once.

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3. Research methodology

The methodology of this study is based on the theory of human capital – G. Becker's classic study of how investment in an individual's education and training is similar to business investments in equipment (Becker, 1993, 2009; Becker et al. 2010), as well as on the theory of long-run growth (Romer, 1986, 1989a, 1989b; Barro, 2001; Barro & Sala-i-Martin, 2004). The main postulates of the theory of human capital and the theory of long-run growth, which the author uses to conceptualize the economic usefulness of older workers in terms of productivity, are the following:

- human beings can increase their productive capacity through greater education and skills training;
- productivity continues to increase due to on-the-job training investments.

Thus, the theory of human capital and the theory of long run growth point to lifelong learning as one of the most significant factors determining the economic usefulness of older workers in terms of productivity. The report on the Global Talent Competitiveness Index provides empirical data on the integrated indicator of lifelong learning in the countries of the modern world. This indicator includes the following structural elements (Lanvin & Monteiro, 2021):

- business and economics subject ranking – the World University Rankings in the subject "Business and Economics". The value is derived from the average score of the top three universities per country;
- prevalence of training in firms – this indicator refers to the percentage of firms that offered formal training programmes in the last complete fiscal year for its permanent, full-time employees;
- employee development – an average answer of experts to the question: In your country, to what extent do companies invest in training and employee development? (1 – not at all; 7 – to a great extent);
- formal and non-formal studies – this indicator refers to the share (%) of adults aged 16–65 who participated in formal and non-formal education and training in the 12 months prior to the interview.

Another significant factor potentially determining the economic usefulness of older workers in terms of productivity is longer working life, which according to the findings of PwC Global's study unlock a potential 3.5 USD trillion prize (PwC Global, 2018). In this study, the author uses the indicator of life expectancy at birth in the countries of the modern world (World Health Organization, 2020) as a characteristic that directly determines the very possibility of longer working life in a particular country. As the data of Table 1 in the previous section of the article showed, in countries with a relatively high productivity of the economy, men's average life duration after retirement, indicating the health status of the retiring workforce, in all compared cases is higher – sometimes 2 times – than in countries with a relatively low productivity of the economy.

The last significant factor that potentially determines the economic usefulness of older workers in terms of productivity is proposed within the conception of endogenous growth (Romer, 1986; Diene et al., 2016). The conception of endogenous growth emphasizes the role of technology and employment in knowledge-intensive industries and justifies the importance of investment in human capital. Investments in human capital have a positive multiplier effect on the economy and slow down the decline in the return on accumulated capital by stimulating people's innovative activities and extending their working life. Within this study, the author uses the indicator of country's technological readiness, calculated for the countries of the world by the World Economic Forum in the Global Competitiveness Report. Although this indicator was last calculated in 2017 (Schwab & World Economic Forum, 2017), the author considers it suitable for this study. Even if the technological readiness of the world's countries itself has changed during this time (most likely upwards), the ratio of technological readiness between countries has not changed enough to distort the results of quantitative analysis. For example, the US is still much more technologically advanced than Latvia (and this is exactly what the author needs to know in order to empirically prove the hypothesis of this study).

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The indicator of country's technological readiness includes the following structural elements (Schwab & World Economic Forum, 2017):

- availability of latest technologies – a weighted average answer of experts to the question: In your country, to what extent are the latest technologies available? (1 – not at all; 7 – to a great extent);
- firm-level technology absorption – a weighted average answer of experts to the question: In your country, to what extent do businesses adopt the latest technologies? (1 – not at all; 7 – to a great extent);
- FDI and technology transfer – a weighted average answer of experts to the question: To what extent does foreign direct investment (FDI) bring new technology into your country? (1 – not at all; 7 – to a great extent);
- Internet users – the share (%) of individuals using the Internet;
- fixed-broadband Internet subscriptions – fixed-broadband Internet subscriptions per 100 population;
- Internet bandwidth – international Internet bandwidth (kb/s) per Internet user;
- mobile-broadband subscriptions – active mobile-broadband subscriptions per 100 population.

The main concepts of this study – the workforce aging and productivity, the relationship between which has to be empirically proven. There are two methodological questions: the empirical interpretation of these concepts and the discovery of causal relationships between them. For the empirical interpretation of productivity, the author uses the experience of studies in which productivity at the macroeconomic level is empirically interpreted and measured using gross domestic product (GDP) per capita, which takes into account the difference between territories in terms of population (Rice & Venables, 2004a, 2004b; Cusolito & Maloney, 2018). In turn, for the empirical interpretation of the workforce aging, the author uses the indicator of retirement age for men (Trading Economics, 2022).

Then, the economic usefulness of older workers in terms of productivity will be empirically proven if the author manages to detect not only correlational parallelism, but also causal relationships between retirement age and GDP per capita (PPP) in 63 countries of the world included in object of this study. Since it is often very difficult to prove causality, the analysis will actually quantify correlation, and then we can either assume that correlation indicates causation (which is risky) (Keim, 2020) or attempt to demonstrate causation by applying additional methods of quantitative data analysis. The author will begin the data analysis by calculating the correlation between the indicators of retirement age for men and GDP per capita (PPP) – both general and partial correlation. In partial correlation, the influence of three factors that potentially determine the economic usefulness of older workers in terms of productivity will be blocked: lifelong learning, average life expectancy at birth and technological readiness in the country. Further, the author will apply additional methods of quantitative data analysis – linear regression (with a stepwise method of including variables) and cluster analysis – in order to confirm the causal relationships between retirement age and GDP per capita (PPP), as well as those conditions that are supposedly necessary for economic usefulness of older workers in terms of productivity.

In the following figure, the author schematically presented the hypothesis of this study, which requires proof: in the modern world, the economic usefulness of older workers in terms of productivity is determined, in addition to the characteristics of the elderly workforce, by factors characterizing the level of country development.

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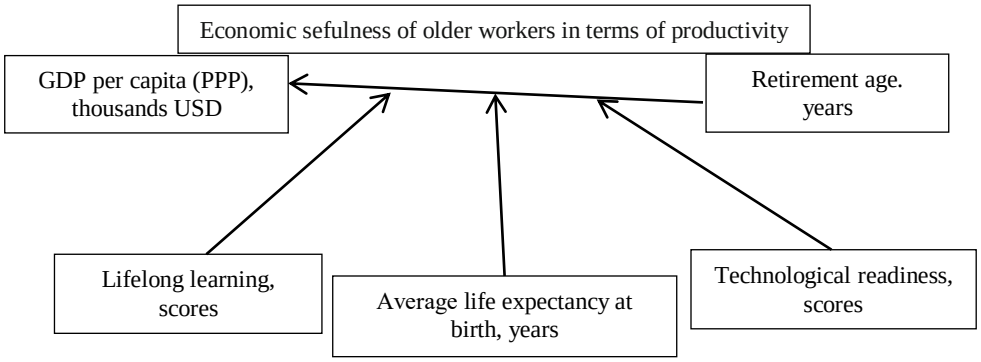

Figure 1. Hypothetical economic usefulness of older workers in terms of productivity, determined by the level of country development

Source: elaborated by the author.

The scheme presented in Figure 1 shows that increasing a country workforce's retirement age, as an indicator of workforce aging, hypothetically stimulates macroeconomic productivity measured by GDP per capita (PPP). This proves the economic usefulness of older workers in terms of productivity, but only on the condition that a sufficiently high level of lifelong learning, average life expectancy at birth and technological readiness are achieved in this country. Otherwise, it is impossible to increase macroeconomic productivity in a country with a low level of lifelong learning, average life expectancy at birth and technological readiness by just raising retirement age. In other words, the economic usefulness of older workers in terms of productivity is determined not so much by the characteristics of the workforce as by the level of development of a country that is able or unable to effectively use the "specific human capital" (Becker, 1993) of older workers.

4. Results and discussion

In accordance with the algorithm presented in the research methodology, the author will begin the data analysis by calculating the correlation between the indicators of retirement age for men and GDP per capita (PPP) – both general and partial correlation. In partial correlation, the influence of three factors that potentially determine the economic usefulness of older workers in terms of productivity will be blocked: lifelong learning, average life expectancy at birth and technological readiness in the country. To assess the effect from blocking variables, the author will also include them in the general correlation analysis. The following table presents the results of correlation analysis between five variables (Fig. 1), showing the degree of correlational parallelism between them, but not causal relationships.

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Table 2. The results of correlation analysis between the variables included in the proof of the research hypothesis, Pearson correlation coefficient, n = 63 countries

Variables	Correlation with GDP per capita (PPP), thousands USD, 2020	Statistical significance, p-value
Retirement age for men, years, 2020-2021	0.397**	0.001
Lifelong learning, scores, 2021	0.744**	0.000
Men's average life expectancy at birth, years, 2020	0.702**	0.000
Technological readiness, scores, 2017	0.826**	0.000

** Correlation is significant at the 0.01 level (2-tailed).

Source: calculated and elaborated by the author using SPSS software based on the data of Lanvin & Monteiro, 2021; Trading Economics. 2022; World Health Organization, 2020; Schwab & World Economic Forum, 2017 (data set is provided in the Appendix).

The results of the general correlation analysis presented in Table 2 show that there is a statistically significant (p-value < 0.05) correlation between GDP per capita (PPP) and all other variables included in the proof of the hypothesis. But this relationship is especially strong not between retirement age for men and GDP per capita (PPP), but between GDP per capita (PPP) and all the significant factors presented in the research methodology that potentially determine the economic usefulness of older workers in terms of productivity – especially between GDP per capita (PPP) and technological readiness.

In the following table, the author compares the results of a general and partial correlation analysis between retirement age for men and GDP per capita (PPP). A partial correlation analysis shows a correlation between retirement age for men and GDP per capita (PPP) if we alternately block the effects of such variables as lifelong learning, men's average life expectancy at birth and technological readiness in a country.

Table 3. Comparison of results of general and partial correlation analysis between retirement age for men and GDP per capita (PPP), Pearson correlation coefficient, n = 63 countries

Variables	GDP per capita (PPP), thousands USD, 2020	Statistical significance, p-value
Retirement age for men, years, 2020-2021	0.397**	0.001
Results of partial correlation between retirement age for men and GDP per capita (PPP), when the effect of the following variables is blocked:		
Lifelong learning, scores, 2021	0.256	0.044
Men's average life expectancy at birth, years, 2020	0.063	0,625
Technological readiness, scores, 2017	-0.141	0.274

** Correlation is significant at the 0.01 level (2-tailed).

Source: calculated and elaborated by the author using SPSS software based on the data of Lanvin & Monteiro, 2021; Trading Economics. 2022; World Health Organization, 2020; Schwab & World Economic Forum, 2017 (data set is provided in the Appendix).

The results of the partial correlation analysis presented in Table 3 show that when the effect of lifelong learning, men's average life expectancy at birth and technological readiness is blocked, the correlation between retirement age for men and GDP per capita (PPP) becomes much weaker (as in the case of blocking the influence of the indicator of lifelong learning) or disappears (as in the case of blocking the influence of the indicators of men's average life expectancy at birth and technological readiness). This is probably because the factors of increasing macroeconomic productivity are, rather, exactly those variables, the influence of which was blocked during the

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implementation of the partial correlation analysis, and not the retirement age itself. A regression analysis will help to define and characterize this putative causal relationship more precisely. In a regression analysis, the resulting variable is the productivity of the economy at the macro level, measured by GDP per capita (PPP), and the factor variables are all other variables included in the proof of the research hypothesis.

$$y = -54.1 + 15.4x_4 + 0.3x_2, \quad (1)$$

where:
y – GDP per capita (PPP), thousands USD, 2020
x_4 – technological readiness, scores, 2017
x_2 – lifelong learning, scores, 2021
Excluded variables:
x_1 – retirement age for men, years, 2020-2021
x_3 – men's average life expectancy at birth, years, 2020

Source: calculated by the author using SPSS software based on the data of Lanvin & Monteiro, 2021; Trading Economics. 2022; World Health Organization, 2020; Schwab & World Economic Forum, 2017 (data set is provided in the Appendix).

The results of the regression analysis show that of all the variables included in the proof of the research hypothesis, the real factors of the increase in macroeconomic productivity are technological readiness and lifelong learning in the country, with the former clearly dominating. Thus, technological readiness, along with a high level of lifelong learning in the country, are the catalysts that ensure the economic usefulness of older workers in terms of productivity in the countries of the modern world.

These results of the author's empirical analysis on a sample of 63 countries of the world are consistent with the results of a sociological survey of economic potential of the population of pre-retirement age conducted in Latvia (Projektu un kvalitates vadiba, 2014). Latvia ranks 37th out of 137 countries in terms of technological readiness (Schwab & World Economic Forum, 2017) and 37th out of 134 countries in terms of lifelong learning (Lanvin & Monteiro, 2021). Latvian researchers found that "explaining the reasons why employers, when choosing workers for their enterprise, would give preference to younger workers and avoid hiring older people, they refer to working conditions (hard, physically intensive work), as well as inflexibility of thinking older workers, difficulties in accepting changes and in learning, their health condition that reduces their ability to work.

The inertia of older people in improving their knowledge, skills and qualifications is also confirmed by the data of a survey of older workers themselves, which show that they are almost two times less involved in lifelong learning than representatives of other age groups" (Projektu un kvalitates vadiba, 2014, p. 68-69). Thus, the results of the Latvian sociological survey on the example of one country also confirm the hypothesis of this study that in the modern world, the economic usefulness of older workers in terms of productivity is determined, in addition to the characteristics of the workforce itself, also by factors characterizing the level of development of the country. Most of all, it is a factor of technological readiness, which makes it possible to minimize the necessity to perform the hard, physically intensive work mentioned by Latvian employers.

To obtain more complete and stable results of empirical analysis, the author will additionally conduct a cluster analysis, dividing the countries into groups based on the all variables included in the proof of the research hypothesis.

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Table 4. Defining the number of clusters of countries based on the all variables included in the proof of the research hypothesis, the part of agglomeration schedule of hierarchical cluster analysis, n = 63 countries

Stage	Cluster combined		Coefficients	Stage cluster first appears		Next stage
	Cluster 1	Cluster 2		Cluster 1	Cluster 2	
1	2	3	0.080	0	0	8
2	14	19	0.098	0	0	4
3	35	51	0.138	0	0	21
…						
60	5	28	8.196	59	57	62
61	1	12	8.667	55	53	62
62	1	5	14.948	61	60	0

Source: calculated by the author using SPSS software based on the data of Lanvin & Monteiro, 2021; Trading Economics. 2022; World Health Organization, 2020; Schwab & World Economic Forum, 2017 (data set is provided in the Appendix).

As the coefficients in the agglomeration schedule of hierarchical cluster analysis presented in Table 4 show, the research object, consisting of 63 countries of the world, is clearly divided into two clusters (the number of countries (63) minus the step number (61), after which the coefficient increases abruptly). The following table shows the results of comparing clusters in terms of means of the variables included in the proof of the research hypothesis.

Table 5. Comparing clusters in terms of means of the variables included in the proof of the research hypothesis, t-test for equality of means, n = 63 countries

Variables	Means of the variables		Statistical significance of differences between clusters, p-value
	Cluster 1 n = 37 countries	Cluster 2 n = 26 countries	
GDP per capita (PPP), thousands USD, 2020	23.2	56.2	0.000
Retirement age for men, years, 2020-2021	63.1	64.3	0.043
Lifelong learning, scores from 0 to 100, 2021	31.6	68.3	0.000
Men's average life expectancy at birth, years, 2020	72.8	79.5	0.000
Technological readiness, scores from 1 to 7, 2017	4.6	5.9	0.000

Source: calculated and elaborated by the author using SPSS software based on the data of Lanvin & Monteiro, 2021; Trading Economics. 2022; World Health Organization, 2020; Schwab & World Economic Forum, 2017 (data set is provided in the Appendix).

The countries of the world participating in the analysis were divided into the two clusters described above as follows:

1) Albania, Algeria, Armenia, Azerbaijan, Bangladesh, Brazil, Bulgaria, Chile, Croatia, Cyprus, Estonia, Georgia, Greece, Hungary, India, Indonesia, Italy, Kazakhstan, Latvia, Lithuania, Malaysia, Mexico, Moldova, Mongolia, Poland, Portugal, Romania, Russia, Serbia, Slovakia, Slovenia, South Africa, Spain, Tajikistan, Turkey, Ukraine, Vietnam (37 countries);
2) Australia, Austria, Belgium, Canada, China, Czechia, Denmark, Finland, France, Germany, Iceland, Ireland, Israel, Japan, Korea, Luxembourg, Malta, Netherlands, New Zealand, Norway, Saudi Arabia, Singapore, Sweden, Switzerland, UK, USA (26 countries).

Thus, the results of the cluster analysis showed a fairly clear division of the countries of the world into two clusters, in the first of which the value of all analyzed variables is statistically significantly lower. This group of countries has relatively lower levels of GDP per capita (PPP), retirement age for men, lifelong learning, men's average life expectancy at birth and technological readiness. Moreover, the indicator of retirement age for men is the only variable, the difference between the means of which in both clusters is very close to the threshold value (0.05). If the p-value for retirement age for men were slightly higher and exceeded the threshold value, then the

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author would have to state that, despite the relatively large difference in the level of GDP per capita (PPP), lifelong learning, men's average life expectancy at birth and technological readiness between the countries of the two clusters, retirement age for men is the same in them. In reality, the countries of the world are very close to just such a situation, indicating a low economic usefulness of older workers in terms of productivity in the countries of the first cluster, determined by the relatively low level of technological readiness and lifelong learning in these countries.

5. Conclusions

Within this study, the author tried to prove that older workers are economically useful in terms of productivity, based on the concept of "specific human capital" by G. Becker (1993) and the conception of endogenous growth stimulated by the technological readiness of the economy. An empirically, the economic usefulness of older workers in terms of productivity was interpreted by the author as a correlation of the country's GDP per capita (PPP) (the indicator of macroeconomic productivity) with retirement age in a country (the indicator of workforce aging). Using several methods of quantitative data analysis for 63 countries of the world, the author proved the hypothesis that in the modern world the economic usefulness of older workers is determined by factors characterizing the level of development of the country, namely: technological readiness as a dominant factor, as well as lifelong learning as an additional factor.

The author also argues that a baseless raising the retirement age in the country, without considering the above factors that characterize the level of development of this country in technological and learning aspects, does not allow the effective use of the economic potential of older workers. Although, perhaps, raising the retirement age is a rather strong incentive for a long-term change in the economic behavior of the population and awareness of the economic efficiency of lifelong learning - not formal, but real and internally motivated. According to the results of a sociological survey of economic potential of the population of pre-retirement age, conducted in Latvia, Latvian employers rate the economic usefulness of older workers rather highly: "only a small number of workers aged 50 and over are assessed by employers as low-skilled and with a poor ability to work. Almost half of employers characterize pre-retirement age workers as not bad specialists who are necessary for the enterprise, and 25% of employers - as very good and needful specialists" (Projektu un kvalitates vadiba, 2014, p. 69).

However, as also shown by the results of previous studies by scientists from Daugavpils University (Latvia) on higher education and its contribution to the economic performance of the world's countries, there are some factors that enable highly skilled specialists to potentially turn their knowledge into innovation and national income. These factors are the quality of higher education and the level of technological development in business (Stankevics et al., 2014). This emphasis on the technological development of the country, confirmed by results of many studies, combined with high-quality lifelong learning, the author considers the most important condition that determines the economic usefulness of older workers in terms of productivity in the countries of the modern world.

The author is ready to argue with the Latvian researchers of economic potential of the population of pre-retirement age, who concluded that "realizing and developing the economic potential of older workers requires specific employment and learning activities specifically targeted at this age group, as well as the support of employers" (Projektu un kvalitates vadiba, 2014, p. 70). Although, based on the results of his empirical research, the author agrees with the importance of lifelong learning for the most efficient use of the economic potential of older workers, he believes that without an appropriate level of technological development of the country, the process of lifelong learning turns into a formal activity "for ticks".

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Appendix

Table 1. Data set of indicators regarding economic usefulness of older workers in terms of productivity, n = 63 countries

Countries	% of people aged 55-64 in employment. 2016	% of people aged 65+ in employment. 2016	Retirement age for men, years, 2020-2021	Men's average life duration after retirement, years, 2020	Men's average life duration after retirement, years, 2020	GDP per capita (PPP), thousands USD, 2020	Lifelong learning, score from 0 to 100, 2021	Transformation readiness, score from 0 to 100, 2020	Technological readiness, scores from 1 to 7, 2017
Albania	No data	No data	65.0	76.3	11.3	13.8	32.2	No data	4.1
Algeria	No data	No data	60.0	76.2	16.2	11.3	13.2	No data	3.4
Armenia	No data	No data	63.0	72.5	9.5	13.3	19.6	No data	4.1
Australia	62.5	25.1	66.0	81.3	15.3	52.5	71.9	62.0	5.7
Austria	49.2	9.3	65.0	79.4	14.4	55.1	70.1	60.3	6.0
Azerbaijan	No data	No data	65.0	68.8	3.8	14.5	30.1	No data	4.6
Bangladesh	No data	No data	59.0	73.0	14.0	5.1	11.3	No data	2.8
Belgium	45.4	4.9	65.0	79.3	14.3	52.0	65.3	63.6	5.9
Brazil	No data	No data	65.0	72.4	7.4	14.8	40.5	51.0	4.6
Bulgaria	No data	No data	64,3	71.6	7.3	24.4	19.6	No data	5.1
Canada	61.6	24.6	65.0	80.4	15.4	48.1	73.7	64.2	5.9
Chile	63.8	38.8	65.0	78.1	13.1	25.1	52.5	53.0	5.2
China	No data	No data	60.0	74.7	14.7	17.3	83.4	65.5	4.2
Croatia	No data	No data	65.0	75.5	10.5	28.5	25.0	No data	5.0
Cyprus	No data	No data	65.0	80.7	15.7	38.5	47.6	No data	5.5
Czechia	58.5	10.7	63.8	76.3	12.5	41.7	51.6	54.0	5.5
Denmark	67.8	15.3	66.5	79.6	13.1	60.4	70.6	66.5	6.1
Estonia	65.3	29.2	63.8	74.7	10.9	38.4	51.3	61.0	5.9
Finland	61.4	14.1	63.8	79.2	15.4	51.1	71.4	69.9	6.0
France	49.8	5.9	62.0	79.8	17.8	46.2	64.7	62.7	5.9
Georgia	No data	No data	65.0	68.8	3.8	14.9	15.2	No data	4.3
Germany	68.6	14.5	65.8	78.7	12.9	53.7	71.7	62.9	6.2
Greece	36.3	7.9	67.0	78.6	11.6	28.5	24.2	47.2	4.8
Hungary	49.9	4.6	64.5	73.1	8.6	33.1	37.6	48.1	5.1
Iceland	84.6	54.4	67.0	80.8	13.8	55.2	51.8	No data	6.2
India	No data	No data	60.0	69.5	9.5	6.5	36.5	49.5	3.1
Indonesia	No data	No data	57.0	69.4	12.4	12.1	22.4	55.3	3.9
Ireland	57.2	19.5	66.0	80.2	14.2	93.6	57.1	60.9	6.0
Israel	66.5	36.4	67.0	80.8	13.8	41.9	49.2	62.7	6.2
Italy	50.3	8.6	67.0	80.9	13.9	41.8	36.4	51.9	5.1
Japan	71.6	41.5	65.0	81.5	16.5	42.2	66.4	61.9	6.0
Kazakhstan	No data	No data	63.0	70.0	7.0	26.7	25.4	No data	4.6
Korea	66.1	44.8	62.0	80.3	18.3	43.1	56.9	61.2	5.6
Latvia	No data	No data	63.8	70.6	6.8	32.0	45.1	No data	5.3
Lithuania	No data	No data	64.0	71.2	7.2	38.7	39.6	No data	5.6
Luxembourg	39.6	5.3	65.0	80.6	15.6	118.4	70.1	No data	6.5
Malaysia	No data	No data	60.0	72.6	12.6	27.9	46.6	No data	4.9
Malta	No data	No data	63.0	79.9	16.9	42.6	49.6	No data	5.9
Mexico	54.9	38.1	65.0	73.1	8.1	18.8	40.6	46.9	4.2
Moldova	No data	No data	63.0	69.3	6.3	13.0	21.3	No data	4.6
Mongolia	No data	No data	60.0	63.8	3.8	12.1	27.9	No data	4.2
Netherlands	63.5	13.1	66.3	80.4	14.1	59.2	78.2	66.3	6.3
New Zealand	76.1	40.6	65.0	80.4	15.4	44.3	70.1	64.0	6.1
Norway	72.6	28.9	62.0	81.1	19.1	63.2	64.2	No data	6.1

Poland	46.2	9.5	65.0	74.5	9.5	34.3	28.1	48.8	4.9
Portugal	52.1	18.2	66.5	78.6	12.1	34.5	44.5	56.1	5.7
Romania	No data	No data	65.0	72.0	7.0	31.9	17.3	No data	4.8
Russia	No data	No data	60.5	68.2	7.7	28.2	28.2	50.4	4.5
Saudi Arabia	No data	No data	60.0	73.1	13.1	46.8	52.0	No data	4.9
Serbia	No data	No data	65.0	73.5	8.5	19.2	28.2	No data	4.2
Singapore	No data	No data	62.0	81.0	19.0	98.5	81.7	No data	6.1
Slovakia	49.1	5.2	62.7	74.8	12.1	31.8	44.8	49.7	5.1
Slovenia	38.6	6.7	60.0	78.6	18.6	39.6	47.8	No data	5.4
South Africa	No data	No data	60.0	62.2	2.2	12.1	24.0	50.4	4.6
Spain	49.1	4.9	66.0	80.7	14.7	38.3	50.2	56.5	5.7
Sweden	75.5	21.9	62.0	80.8	18.8	54.6	77.8	68.5	6.3
Switzerland	73.9	21,9	65.0	81.8	16.8	71.4	89.7	62.5	6.4
Tajikistan	No data	No data	63.0	67.6	4.6	3.9	16.5	No data	3.0
Turkey	33.4	19.4	60.0	76.4	16.4	28.1	29.3	45.2	4.4
UK	63.4	21.1	66.0	79.8	13.8	44.9	77.2	61.4	6.3
Ukraine	No data	No data	60.0	68.0	8.0	13.1	28.5	No data	3.8
USA	61.8	30.8	66.2	76.3	10.1	63.5	90.1	62.2	6.2
Vietnam	No data	No data	60.0	69.6	9.6	8.7	21.5	No data	4.0

Source: elaborated by the author based on the data of PwC Global, 2017; Lanvin & Monteiro, 2021; Trading Economics. 2022; World Health Organization, 2020; Schwab & World Economic Forum, 2017.

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Data Availability Statement: all data provided in the Appendix

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INNOVATIONS AND THE CIRCULAR ECONOMY: A NATIONAL AND REGIONAL PERSPECTIVE

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Abstract. The introduction of innovative practices compatible with the objectives of the circular economy is one of the main enablers for transforming current production patterns towards more sustainable and competitive systems. Understanding whether and to what extent firms are introducing circular-oriented innovations allows monitoring where we stand in the circular transition and thus which further efforts are needed to achieve a resource-efficient economy. This study is based on data from two surveys on Small and Medium Enterprises: the first one reaches 4565 companies located throughout Italy (in the two-year period 207-2018) and the second one focuses on 1603 companies operating in the Emilia-Romagna region (in the three-year period 2017-2019). The analysis is aimed at offering a broad picture of the level of involvement of national and regional firms in the implementation of circular innovation. Despite the overall positive performance, there appears to be a fragmented adoption of circular innovation in terms of firms' size, technological intensity of the sectors and in accordance with the geography and the productive specialization of the territory. In general, circular innovation mainly involves firms operating in low-technology-intensity sectors in Southern Italy and more technological intensive sectors in Northern Italy and it is more widespread among large firms. On the contrary, in Emilia-Romagna, the distribution of circular innovation mainly concerns medium-sized firms, especially those belonging to low and medium technology-intensive sectors, moreover companies in the provinces of Modena and Parma show higher adoption rates.

Keywords: Circular Economy, Eco-Innovation, Circular Innovation, Small and Medium Enterprises, Business Models, Regional Studies

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JEL Classifications: R1

Introduction

In the context of decoupling strategies (Mazzanti and Pronti, 2021) between economic growth and negative anthropogenic impacts on the environment (e.g. CO2 emissions), the Circular Economy (CE) represents one of the main pillars aimed at supporting the adoption and diffusion of innovation within the European Green Deal (Kemp et al., 2019). The envisaged framework of transition to emission-neutral economies, with the elimination

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of landfilled waste and overall low environmental impacts, poses crucial challenges for companies, which should embrace the CE objectives through the introduction of new processes and products (Barbieri et al. 2016). In order to make sustainability (e.g. circular business models) and competitiveness complementary, by turning the potential costs of more stringent environmental policies into competitive advantages, it is crucial to adopt environmental innovations along with organizational, technological and human resource management innovations (Antonioli and Mazzanti, 2009; Antonioli et al., 2013). This will allow creating complementarities aimed at increasing both social and environmental economic performances. Accordingly, in order to pursue the goal of competitiveness and sustainability, circularity should foster practices of participation and involvement of workers and stakeholders.

The concept of CE is indeed calling for the introduction of radically alternative business models compared to traditional linear modes of production and consumption. This transition will ensure the generation of profits and the maintenance of companies' competitiveness within the context of the increasing pressure to which production and consumption subject the global availability of resources. Price volatility, resource supply risks and accessibility to scarce materials have in fact become factors of great concern in order to continue to guarantee firms' competitiveness. In this scenario, the CE paradigm has been recognized as a high-potential solution capable of reorienting the traditional economic approach by changing the linear mindset of industry. In this model, indeed, resource conservation becomes the core of a new regenerative business approach, in which materials flow within a single closed loop. In this way, «the value of products, materials and resources is maintained in the economy for as long as possible, and waste generation is minimized» (European Commission 2015 p. 2).

As recognized in Bocken et al., (2016), firms can operate on several levels of circularity. The first is properly concerned with *closing material loops* through material recycling and/or recovery practices. The second level concerns *slowing material loops* through the production of more durable goods or the spread of reuse, repair and re-manufacturing activities. Finally, the third level of circularity supports the *narrowing of material loops* through more efficient and intensive use of resources and the replacement of material goods with immaterial services, which also involve consumer participation. Therefore, the design phase becomes the starting point for the development of products or services based on the principles of longevity, reuse/recovery, maintenance, recycling and dematerialization. In general, the goal is to develop new business strategies that create value based on minimizing material inputs, maximizing economic output, and respecting environmental limits (Flachenecker and Rentschler, 2019).

On the other hand, the transformation of conventional business models towards circularity cannot ignore the support of new technologies, processes and organizational structures. Maintaining current economic standards while decreasing resource use and waste accumulation requires innovation to play a key role in the circular reorganization of current production paradigms. In fact, innovation, and more specifically Eco-Innovation (EI), has been recognized as the catalyst for CE at the company level. The debate on EI has adopted different theoretical perspectives to better understand its features, dynamics, determining factors (Arundel and Kemp, 2009; Beise and Rennings, 2005; Berkhout 2011; Cainelli and Mazzanti, 2013; Marin, 2014; Jabbour et al., 2015) and its relation with the CE transition process (Cainelli et al., 2020). The traditional literature related to EI distinguishes between product, process, and organizational innovations, but concerning the link between EI and CE, Carrillo-Hermosilla et al., 2010 have most importantly highlighted the difference between incremental and radical forms of EI. Product and process EIs mainly represent technological solutions based on, among others, conservation and efficient resource management or design of long-lived, decomposable, repairable products. However, above all, achieving a new circular model requires systemic changes. Therefore, the introduction of non-technological EIs are necessary to promote new organizational models capable of inducing radical transformations within current production and consumption patterns. As pointed out in de Jesus et al, (2019) «merging technological and non-technological change into a new, cleaner techno-paradigm has been referred to as 'systemic EI' leading to the deeper promise of a circular transition». In this definition, EI is considered not only as

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an effective tool to achieve CE, but also as a vehicle for a higher level of sustainability, i.e. strong sustainability (Maldonado-Guzmàn et al., 2020).

It emerges that firms' ability to change current business models in a circular fashion way depends on their ability to make incremental and radical eco-innovations interact, in a context where incremental eco-innovations act as a tool to support more radical changes. In this view, circular EI is a combination of knowledge types driven on the one hand by R&D, cost reduction processes, and technical solutions embedded in cleaner products and processes, and on the other hand by new institutional organizations, business and behavioral models inscribed in circular organizational solutions (de Jesus et al., 2019, p. 1496). This shift is undoubtedly complex, hence it is important to assess the state of the art of the circular transition at the company level with the aim of identifying existing gaps, preparing solutions, and thus accelerating the action plan. This analysis needs to take place not only at the national level but especially at the local level. In fact, cities and regions have a central role in promoting CE because local and regional governments hold core competencies in most of the policy areas that underpin a circular change (e.g., waste management, water), and they are additionally more aware about the industrial network of their territory.

In this regard, the research center CERCIS of the Department of Economics and Management of the University of Ferrara, has conducted two surveys, at this stage, aimed at measuring the adoption of circular innovations in Italian and Emilia-Romagna manufacturing companies, with the aim of providing information and material for analysis and study to policy-makers and national and local stakeholders. This aims not only to raise awareness on the issue of circular innovations in companies, but also to provide a knowledge base that can be used to develop and design more conscious economic and managerial policies of green human resource management. The following paragraphs will show the distribution of circular innovations at the enterprise level, both on the national and regional territory, with a particular focus and disaggregation of innovations at the level of the Emilia-Romagna region.

Surveys on manufacturing enterprises: national survey and regional survey of Emilia-Romagna

The two surveys conducted at the company level have the following characteristics.

The national survey on manufacturing companies with at least 10 employees was conducted in 2020 by the survey company Izi s.p.a.. This survey was configured as a CAWI (Computer Assisted Web Interview) survey through which a structured questionnaire was administered to companies. This questionnaire is made up of 4 main macro-sections: Business Characteristics; Innovation and Investment; CE; Organization, Training and Industrial Relations. Within each section, an appropriate set of questions allows for the collection of relevant information on the various themes. Although the questionnaire is complex, the objective of interviewing at least 4500 companies at national level has been achieved: the sample of responding companies is 4565, stratified on three dimensions - geographical location (macro area, Istat), sector (technological intensity, Eurostat), size (10-49 employees; 50-249 employees; 250+ employees). The period covered by the national survey is the two-year period 2017-2018. For the national economy it represents a two-year period of growth, which had already begun in 2015, but which showed a phase of slowdown in the transition from 2018 to 2019 (albeit still growth).

As for the regional survey, in the Emilia-Romagna region, the characteristics are similar to the national one described above: a survey conducted by Izi s.p.a. through the CAWI method on regional manufacturing companies. However, several aspects significantly distinguish the regional from the national survey. First of all, the reference period is the three-year period 2017-2019; secondly, the investigated firms involve also micro enterprises (information was also collected for a limited sample of enterprises with less than 10 employees); finally, on the one hand questions on supply chain strategies have been added to the sections of the questionnaire and a new section on the impacts of the pandemic crisis (COVID-19: impact and strategies) has been introduced.

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On the other hand, the Organization, Training and Industrial Relations sections are not present. In the regional context, 1603 firms have been interviewed

Dissemination of Circular Innovations (CI)

In order to understand the diffusion framework of circular innovations (CI), we will lead an analysis on two levels, in accordance with data collected from the surveys: the national level and the regional level. On each macro level, we will provide information on the diffusion of CI along three dimensions: 1) the economic sector to which the company belongs, in terms of the technological intensity of the sector itself (Low technological intensity; Medium-low technological intensity; High technological intensity; Medium-high technological intensity)[*]; 2) the size of the company in terms of employees (under 10 employees only for the regional survey-Micro; 10-49 employees-Small; 50-249 employees-Medium; 250+ employees-Large); 3) the geographical localization of the company - regional in the analysis of national diffusion and provincial in the analysis of regional diffusion.

The national context

At the national level we represent the distribution of circular innovation defined as a binary variable CI for the biennium 2017-2018. If a company declares that it has adopted at least one innovation aimed at achieving one of the following CE- related objectives indicated in the questionnaire - Reduction in the use of water in the production process; Reduction in the use of materials; Use of energy generated from renewable sources; Reduction in the use of electricity; Reduction in waste emitted (per unit of output produced); Reuse of waste in the production cycle; Transfer of waste to other companies that use it in their own production cycle; Change in product design to minimize the use of raw materials (including energy); Change in product design to maximize recyclability; Change in production process to reduce greenhouse gas emissions - then the variable takes a value of 1. Otherwise it takes a value of 0. The average of this binary variable provides the percentage distribution. At the national level, about 43% of companies claim to have adopted at least one of the circular innovations indicated, with differences in the spread at the regional level, as emerges from Figure 1. In addition, it results that, despite some exceptions, CI tend to be concentrated in regions where the industrial sector weighs heavily on the regional total[†]. We can assume that these are 'driven' by both industry diffusion and manufacturing specializations within each region. However, we also need to consider the time dimension to which the questions about CI deployment refer: the 2017-2018 biennium. Since there are certainly asynchronies in the diffusion of CI, it is possible that some regions will be less innovative in that two-year period because responding firms were already very active in introducing CI prior to 2017-2018. On the other side, it is interesting, while waiting for new survey data on 2019-20, that we do not observe a fairly typical north-south divide in the rate of innovation, confirming that the country is on average at high levels of performance on circularity issues[‡]. On the other hand, we must also remember the Italian R&D deficit, still more than 1.5 GDP points away from the European target of 3% R&D per share of GDP, and almost 3 GDP points away from leaders such as South Korea. The effort over the next five years must be to raise private and public R&D, and specifically the number of researchers and graduate and highly qualified personnel in companies.

[*] https://ec.europa.eu/eurostat/statisticsexplained/index.php?title=Glossary:Hightech_classification_of_manufacturing_industries
[†] Source https://www.infodata.ilsole24ore.com/2014/11/26/la-mappa-delle-imprese-in-italia-scopri-la-vocazione-di-ciascuna-regione/?refresh_ce=1

[‡] https://ec.europa.eu/eurostat/web/circular-economy/indicators

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Figure 1. Distribution of circular innovation (CI) in the different Italian regions (4565 responding companies)
Source: National Survey, Cercis, 2020

As shown in the following figure (Fig. 2a,b), the distribution of the CIs seems to be linked to the technological intensity of the sector to which the company belongs, but in an opposite manner with respect to the context of the two Italies (Fig.3): North and South. Responding companies belonging to sectors with low and medium-low technological intensity are mainly concentrated in southern regions (Fig. 3). Within these sectors, in southern regions, the CI in the period 2017-2018 tends to be more widespread. In Southern regions, CI is not an issue for firms in technology-intensive sectors. On the contrary, low-tech sectors tend to be more sensitive to CI: this probably depends on the types of production processes and potential efficiency/cost gains that CI can bring to firms. On the other hand, by observing the companies' distribution in the North, we see that, to a relatively high diffusion of CIs in some regions, there is an associated low diffusion of responding companies in sectors with low technological intensity. Indeed, the greatest diffusion of CIs, in various regions of the North, characterizes sectors with the highest technological intensity, even though the diffusion in sectors with low technological intensity remains high. In terms of distribution by company size, we see that large companies are the most active in introducing CI.

The brief presentation of data on the distribution of CIs in the national context and their heterogeneity in terms of spread along the three dimensions analyzed opens the way to the analysis of distributional heterogeneity at the regional level.

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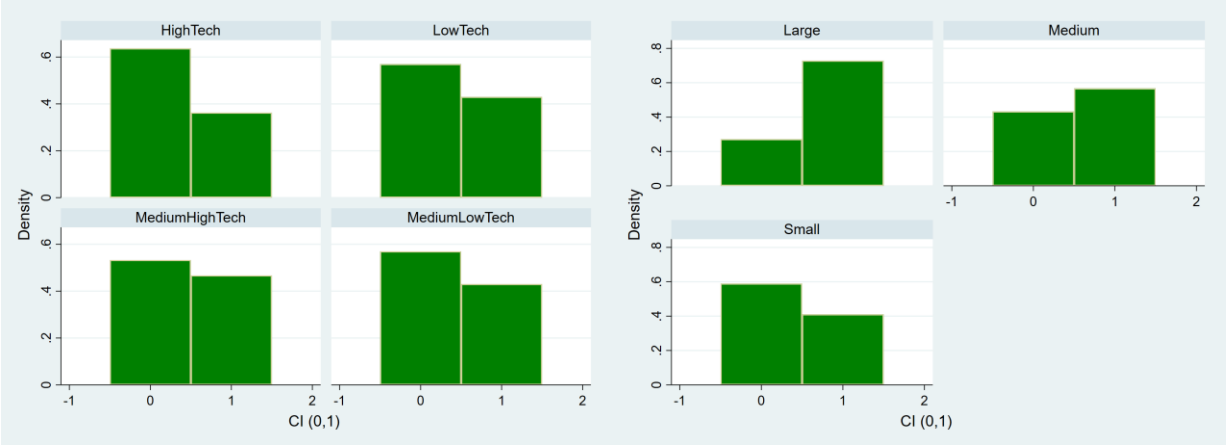

(a) **(b)**

Figure 2a,b. Distribution of CI by sector (based on technological intensity) and company size (based on number of employees)
Source: National Survey, Cercis, 2020

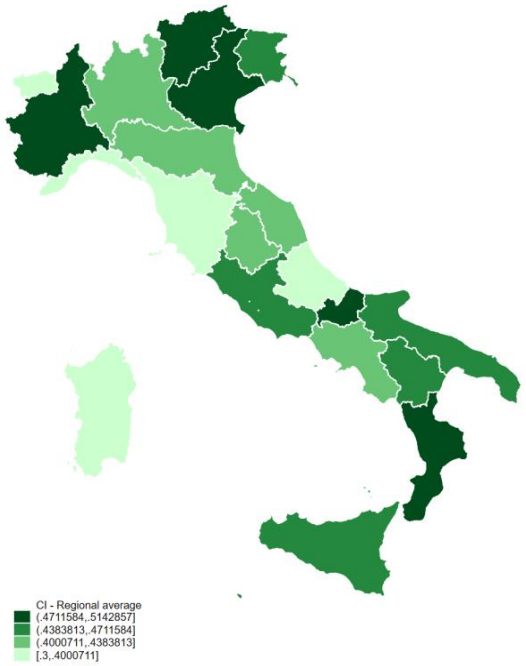

Figure 3. Distribution of medium-low and low-tech enterprises by region
Source: National Survey, Cercis, 2020

The regional context

As far as the regional context of Emilia-Romagna is concerned, we note that, the size variable has a different impact than in the national context, in terms of business characteristics that potentially influence the decision to adopt CI (Fig. 4). In terms of adoption, medium-sized companies have a performance similar to and, at the margin, superior to that of large companies. Therefore, it seems that in the regional context, medium-sized companies are more active than in the national context. This also happens for the introduction of other types of

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innovation (in particular, product innovation), leading to the hypothesis that the medium size, within the regional productive context, gives companies the ability to overcome both the inertia of large organizations and the difficulties generated by small size (e.g., scarcity of financial resources, difficulty in accessing credit). Specifically, data show that medium-sized companies, particularly those belonging to sectors of low to medium technological intensity, have introduced a higher percentage of circular innovations in the three-year period 2017-2019. These are followed by large companies, especially those belonging to sectors of medium-high technological intensity, and micro enterprises in sectors of high technological intensity. On the other hand, small enterprises are at the tail end, among which those belonging to medium-high technology intensity sectors stand out for the implementation of innovations related to CE strategies.

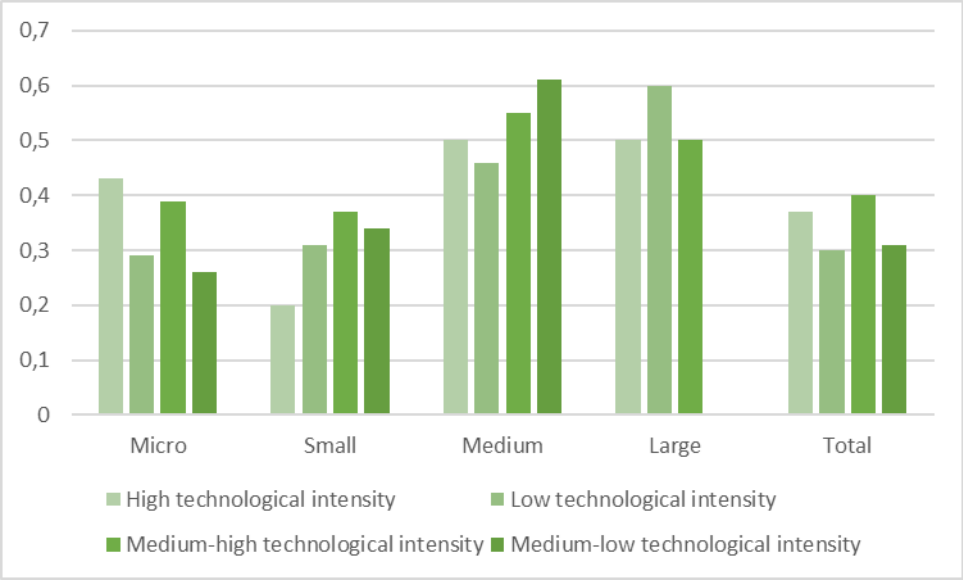

Figure 4. CI in Emilia-Romagna by sector (based on technological intensity) and firm size (based on number of employees) - 2017-2019 (1603 responding firms
Source: Survey regionale, Cercis, 2020

At the province level, the distribution of the CI variable shows the characteristics of Fig. 5. The companies that most frequently report introducing at least one CI in the three-year period 2017-2019 are situated in the provinces of Modena and Parma, then come Bologna and Ferrara followed by Rimini and Reggio Emilia. The provinces of Ravenna, Forlì-Cesena and Piacenza close the ranking. The national heterogeneity in the geographic distribution of circular innovations is also found at the regional level, when dividing the territory into provinces. Each province is characterized by specific production specializations and, in some cases, by industrial networks organized into districts (e.g. biomedical in the province of Modena).

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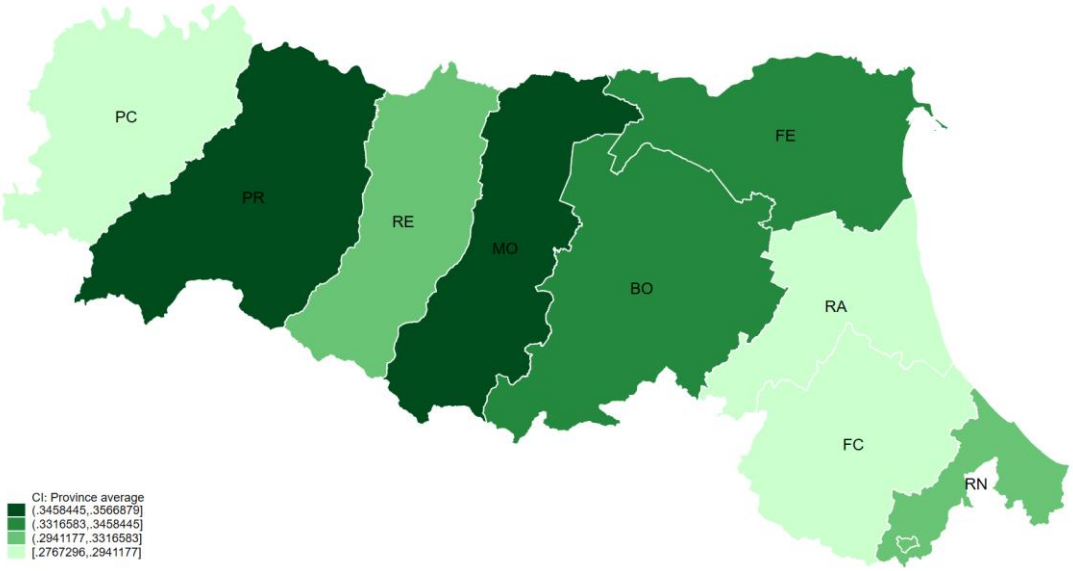

Figure 5. Distribution of circular innovation (CI) in the different provinces of Emilia-Romagna
Source: Regional Survey, Cercis, 2020

Turning to the specific types of CI (Reduction of raw materials; Waste reduction; Design for durability; Design change to reduce resources; Replacement with biomaterials; Design for reparability; Transfer of waste to other companies; Reduction of electricity; Use of renewable energy; Design for recyclability; Reuse of waste in the production process; Water reduction; Design for disassembly) we can notice the following in terms of distribution by sector and size (Figs.6,7). Out of the total number of companies responding to the survey, the main circular innovations introduced in the three-year period 2017-2019[§] are those aimed at the more efficient use of raw materials (13%), reducing the amount of waste generated per unit of output produced (9%), and changing products' design to increase the durability of goods and reduce the amount of resources needed (8%). Overall, in the introduction of these practices, medium- and large-sized companies and those in high- and medium-high-tech sectors stand out.

[§] To note, the total percentage of responding firms introducing individual circular innovations between the analysis by size and the analysis by sector is slightly different, as adopting the classification by technological intensity of the sector to which they belong loses some responding firms. Therefore, the percentage of circular innovations introduced by firm size is calculated on the overall sample of 1603 firms, while the percentage of circular innovations introduced by firms by sector is calculated on 1578 firms.

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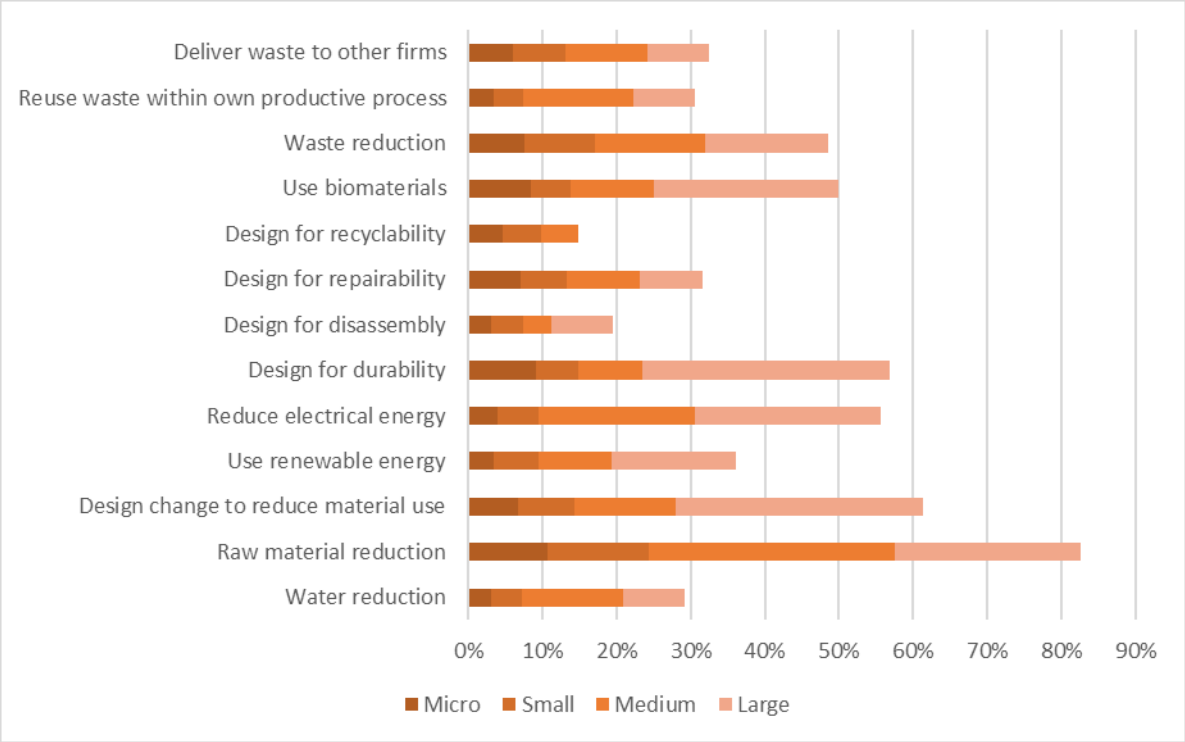

Figure 6. Distribution of the different types of CI by company size
Source: Regional Survey, Cercis, 2020

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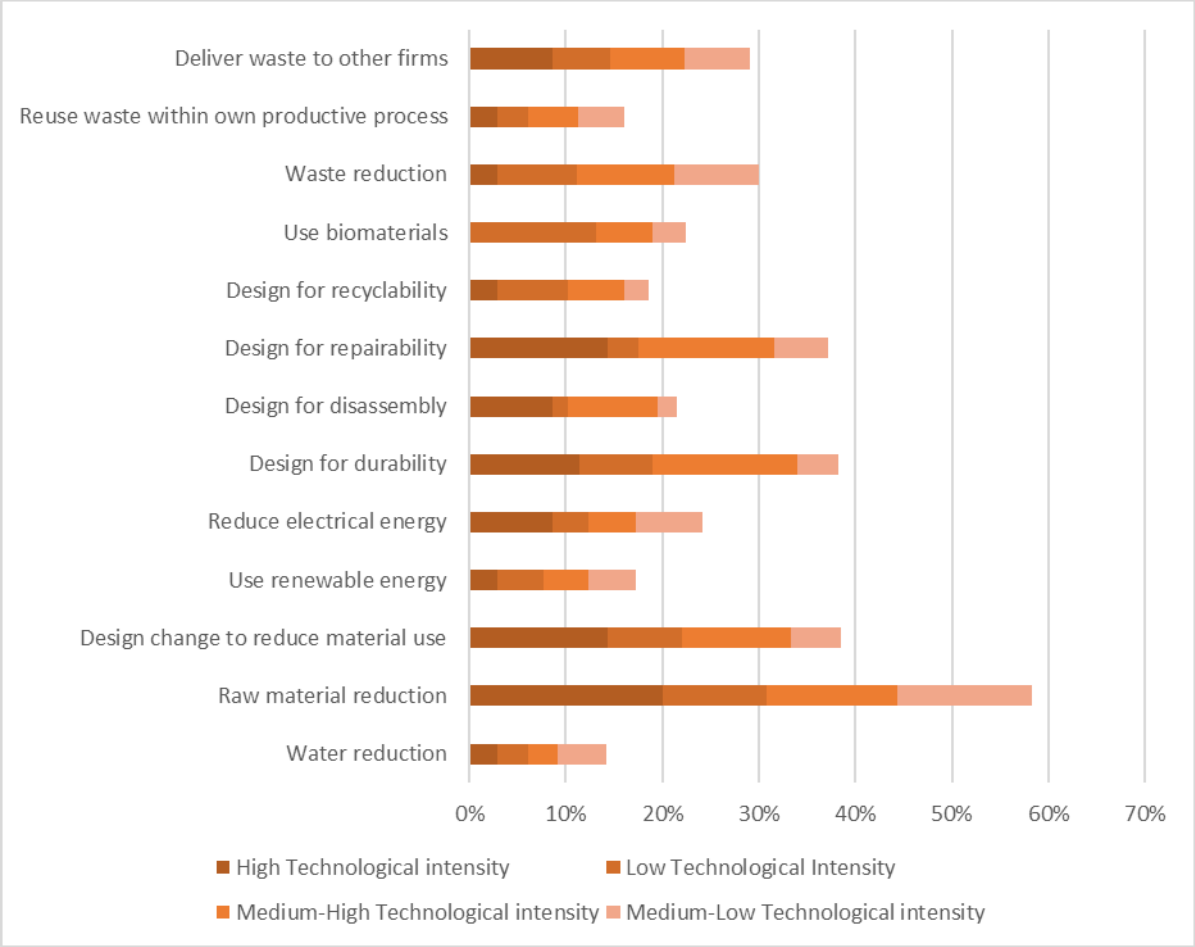

Figure 7. Distribution of the different types of CI by sector of the company (in terms of technological intensity)
Source: Regional Survey, Cercis, 2020

On the side of the geographic distribution of the CI types, we note that some provinces, including Ferrara along with Modena and Parma tend to have a higher diffusion compared to the average in terms of responding companies that declare adopting some of the various types of CI (Fig.8). To note that the average diffusion of CI in respondents is 6% and ranges from 15% for innovations aimed at reducing resources to 1% for design innovations aimed at improving disassembly and durability and for innovations aimed at reducing electricity. Modena has a much higher than average diffusion (gap of about 5%) on innovations aimed at reducing the use of raw materials, increasing reparability, reducing waste and transferring waste to other companies. Parma has a much higher than average diffusion (gap of about 5%) on innovations aimed at reducing the use of raw materials, increasing reparability and reducing waste.

Focusing the attention on the province of Ferrara, it emerges that, according to the sample of respondents, it is the province that has a much higher performance than the average (gap of about 5%) in terms of diffusion of CI with the following aims: to reduce the use of raw materials, to reduce waste, to increase durability, to change the design to reduce the use of resources, to replace existing materials with biomaterials. In the sample of respondents, companies situated in the province of Ferrara seem strongly active on a plurality of CIs aimed at different goals.

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Circular innovations	BO	FE	FC	MO	PC	PR	RA	RE	RN	Total Emilia-Romagna
Water reduction	4%	6%	3%	4%	11%	3%	3%	3%	5%	4%
Raw material reduction	15%	15%	7%	15%	9%	14%	10%	15%	12%	13%
Design change to reduce material use	8%	10%	5%	8%	4%	8%	7%	10%	6%	8%
Use renewable energy	5%	6%	4%	5%	6%	6%	3%	5%	6%	5%
Reduce electrical energy	7%	6%	1%	6%	4%	6%	5%	5%	9%	6%
Design for durability	8%	11%	4%	8%	4%	12%	8%	9%	5%	8%
Design for disassembly	3%	6%	4%	4%	2%	3%	4%	5%	1%	4%
Design for repairability	6%	7%	6%	10%	2%	10%	6%	6%	1%	7%
Design for recyclability	6%	7%	2%	5%	4%	5%	3%	5%	5%	5%
Use biomaterials	8%	10%	8%	6%	6%	6%	10%	7%	6%	7%
Waste reduction	9%	14%	7%	10%	7%	9%	8%	7%	9%	9%
Reuse waste within own productive process	4%	4%	2%	4%	4%	5%	7%	5%	6%	4%
Deliver waste to other firms	8%	6%	6%	9%	5%	4%	10%	4%	5%	7%

Figure 8. Percentage of responding companies that state they adopt the various types of CI by province
Source: Regional Survey, Cercis, 2020

Concluding remarks

The transition from a linear to a circular economy brings with it numerous challenges that companies cannot address without transforming the organizational foundations of their business. This research has focused on CI as a means of transitioning to CE. CI proposes an approach to closing resource cycles, which aims to overcome the limitations of the traditional economic paradigm based on the so-called take-make-dispose. The aim is to identify new models of production and consumption that ensure environmental protection without sacrificing economic growth priorities (Zoboli, 2018). It is an operational approach that integrates a number of strategies: from the minimization of raw materials and waste, to the extension of the life cycle of products, to the efficient use of resources, in which innovation plays a key role. Through the development of two surveys, at the national and regional level, this research focused on the level of implementation of CI among Italian manufacturing companies (in the two-year period 2017-2018) and Emilia-Romagna (in the three-year period 2017-2019). The objective is twofold, on the one hand to transfer and increase the knowledge of companies on the topic so that they can draw a competitive advantage from it, and on the other hand to provide data that positively affect the elaboration of conscious and appropriate economic policies.

The results of the survey showed that, on the national level, CI characterizes 43% of the responding companies. The spread is diversified according to the productive specializations of each specific regional territory. Moreover, while in the southern regions, CI mainly involves companies belonging to low-technology-intensity sectors, in the northern regions, it is mainly companies belonging to more technologically-intensive sectors that declare a greater introduction of CI. From the point of view of size, the distribution of CI is more widespread among large companies. On the other hand, at the regional level, the size variable shows that it is medium-sized companies that are more active in the adoption of CI. As in the national context, however, also at the regional level, the diffusion of CI and the implementation of the different types of CI differs according to the geography of the territory. The companies that most frequently have introduced at least one CI are found in Modena and Parma, while Ravenna, Forlì-Cesena and Piacenza are at the bottom of the list. Among the different types of innovation, those most introduced by Emilia-Romagna companies are aimed at more efficient use of raw materials, reduction of the amount of waste generated per unit of output produced, change in design to increase the durability of goods and to

reduce the amount of resources needed. Companies in the provinces of Ferrara, Modena and Parma are those that perform above average in the adoption of different types of CI. Specifically, Ferrara stands out positively from the average for the introduction of innovations aimed at: reducing the use of raw materials, reducing waste, increasing durability, changing the design to reduce the use of resources, replacing existing materials with biomaterials.

Overall, this survey therefore provides an exclusive picture of the state of the art of the circular transition at the firm level. This is a prerequisite for effective public policies to encourage and reinforce the ultimate implementation of this path of change. On the one hand, environmental, industrial, training and innovation policies must be integrated in order to pursue a broad sustainability that covers a large and interconnected number of SDGs, and on the other hand their design must be oriented both to support innovators towards increasingly radical processes and to help non-innovators get started. The goal is to bring the whole system of territories and sectors, micro, small-medium and large enterprises towards sustainability, through an ecological and fair transition, characterized by increasing investment in training and innovation in companies.

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TRANSITION TOWARDS GREEN FINANCIAL SECTOR FOR GAINING NEWLY PERCEIVED COMPETITIVENESS BY ADOPTING A GREEN MANAGEMENT MODEL

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Abstract. The purpose of the article is to outline the relationship between the green management aspects in the financial sector that lead to the green competitiveness from the external stakeholders' perspective. The methodology used in this study is based on the Preferred Reporting Items for Systematic reviews and Meta-Analyses for Scoping Reviews (PRISMA-SCR) approach seeking to develop a greater understanding of relevant terminology, core concepts, and key factors affecting the transition process towards the green financial sector. The main outcome of this research is constructing a model of transition towards the green financial sector for gaining green competitiveness in which the external stakeholders' perspective hass been emphasized. This study creates a research tool that can be used for weighting green managerial aspects from the external stakeholders' point of view. While performing this study, the authors were focusing on the Middle East area which constitutes the main limitation of this research. Therefore, more attention and focus on other geographical areas might be necessary for more accuracy.

Keywords: transition; sustainable development; green competitiveness; green management; financial sector; stakeholders

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JEL Classifications: F63, G21, M10, O32, Q01

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1. Introduction

In today's competitive world, firms and managers have to consider the market preferences and deliver goods and services that not only meet but also exceed the expectations of their stakeholders. “Green” orientation has become the new managerial shift towards the newly perceived competitiveness. In this sense, businesses have to create a green managerial strategy with enormous potential that can make the companies capable of locating and seizing green resources to offer and provide values to the public while additionally creating green competitive advantages.

Regarding the scope of this study, it stems from the research literature that the so-called “green shift” from the traditional management towards the green management has been a widely-debated subject. Some authors agree that it is a must to “go green” while others think that it is optional with some assuming that it is not significantly important. The discussion is presented further down in this paper.

In this paper, we adopt the following approach: nowadays, business and state companies alike should implement a green management system in order to survive and to be competitive. It is not a question anymore that the effect of the application of green management policy brings positive results for the company, since the perception of the company’s competitiveness has changed due to the green expectations of its customers.

Moreover, many recent studies are devoted to the analysis of factors and aspects of green management in a number of sectors, such as the financial sectors, educational sector, agricultural sector, and manufacturing sector. In general, as it was already mentioned above, there is almost unanimous agreement about the positive influence of the application of green management on all the above sectors.

Since the present paper focuses on a financial sector, we need to discuss separately the perception of various authors on the importance of green transition, specifically in this sector of economy. Hence, it has to be noted that some authors do not believe that the shift towards the “greener” performance has any sense in financial sector which is comprised of banks, credit and facilities companies, financial services companies, etc. The sceptics claim that the financial companies such as banks, in principle, are neither green nor polluting, since they provide services which do not require using of polluting resources. They state that at the current moment financial sector is not polluting the environment and even if it does, the scale of pollution remains very low. The authors belonging to this strand believe that the pollution or environmental damage caused by the financial sector is not significant. According to them, it is not an important topic for investigation. Here, we need to declare very clearly that the authors of the present paper belong to another strand of the scientists who believe that it is very important to give a momentum for the transition of the financial sector towards greener performance and even gain green competitiveness. The arguments supporting such attitude are presented below.

The financial sector plays an important role in economy and affects other sectors through providing financial services. The financial sector can facilitate evolving such sectors as Green Manufacturing sector, Green Agricultural sector, Green Trading sector, Green Educational sector etc. (Figure 1).

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Figure 1. Green management aspects in the financial sector
Source: created by the authors

Let us explain the impact of financial services on other sectors of economy. It is well known that the two main financial activities are depositing and lending of money. Any big or small project requires some funds to be executed. The financial resources are highly demanded and therefore the power of lending is in the hands of the financial institutions.

This power can be used by the financial sector for facilitation economies transition towards the greener state. By adopting the green lending policy (which will be called "green management") the financial sector by itself will also gain green competitiveness.

2. Previous studies on green management for green competitiveness in the financial sector

Many researchers have found that people are willing to switch from traditional finance to sustainable finance because they prefer green practices such as green awareness, green image, and green products (Shkodina et al., 2019; Khoshnava et al., 2019; Stock et al., 2018; Themistocleous et al., 2015; Asongu et al., 2019; Katta et al., 2019; Flögel & Beckamp, 2019; Strielkowski et al., 2021a; Maixé-Altés, 2015; Ling et al., 2016).

As it has been already mentioned above, the authors of this paper belong to the strand of authors who believe that it is important to facilitate the "greening" of financial sector. Nevertheless, there are still many unanswered questions, such as:

- Is it possible to gain a competitive advantage through the transition to the financial sustainability?
- Will the green lending through banks have an impact on stakeholders' decision-making?
- Is it possible to gain a bigger market share by using green finance?

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This study aims tackles the transition towards greener financial sector via green management activities. It aims to specify green management directions taking into account stakeholders' interests. In order to implement the formulated approach, which is a backbone of the adopted methodology, the task of building a model of green transition towards greener and more competitive financial sectors is set.

In order to build this model, the concept of sustainability is employed. Let us recall that the concept of sustainability embraces some well-known dimensions: economic, human, and environmental. To rephrase, we can say that three dimensions of sustainability state are a must: Economy, People, and Environment.

Since we focus on green management in financial sector, we need to reflect the indicated dimensions, specifically in this sector. Hence, a dimension of Economy is assessed via green products/services, a dimension of People we assessed through green human resources, and the dimension of Environment in the banking sector we assessed via technological specifics which, in our case, is a green lending platform.

In case we admit that the listed dimensions serve as management objects, we could construct a conceptual green management scheme for financial sector (see Figure 2 below).

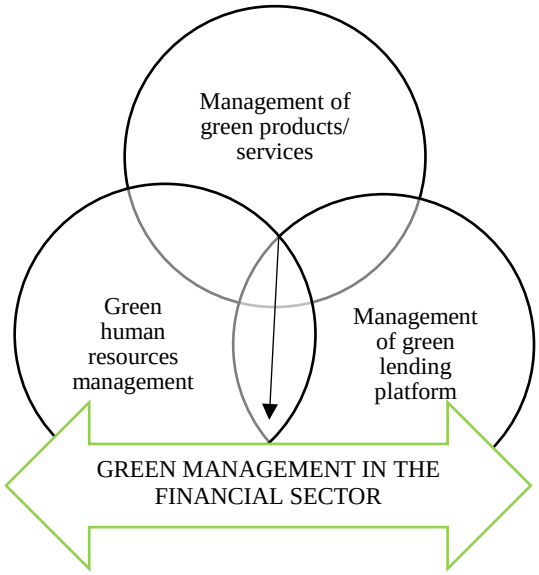

Figure 2. Green management scheme in a financial sector
Source: created by the authors

Relying on the classical definition of competitiveness formulated by Porter (1991), we claim, that the financial sector is able to provide a competitive advantage on the market through the practical use of the green economy management model directed towards environmental protection or healthy and sustainable development goals (Štreimikienė et al., 2014).

Green competitiveness has been widely discussed in some recent literature reviews in which many authors have linked it to the energy consumption and energy-saving competitiveness (Fu et al., 2017a; Tsai et al., 2015; Lu et al., 2019). Others have linked it to the infrastructure, construction and innovation, as well as the economic and

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social sustainable competitiveness (Cheng et al., 2018; Cheng et al., 2019; Barysienė et al., 2015; Abrham et al., 2015). Some scholars have linked it to the employees' skills and human resources competitiveness (Lin & Chen, 2017; Mishra, 2016). In their study, Konuk et al. (2015) claim that competitiveness has the meaning of ecological and environmental competitiveness. Mwesigwa Banya & Biekpe (2016) rather similarly underline economic and social sustainable competitiveness facets. Many researchers use both ecological and economic aspects (Khvesyk et al., 2018; Wang et al., 2016; Maitre et al., 2018; WESO Greening with Jobs, 2018). Some researchers linked it to the competitiveness of natural resources (Abdolvand et al., 2017). The literature on facets of green competitiveness and their interrelation with green management is systemized in Appendix 1, Table 1.

To conclude, three is no unanimous agreement in the recent literature where, specifically, a company has to focus in order to gain green competitiveness. A company could gain a green competitive advantage when improving its waste management, or developing green innovation, having green social impact, or, e.g. fostering green human resources. Although all authors pint to important facets of green competitiveness, a clear definition of green competitiveness is still missing. It is noticeable, that the recent literature links green competitiveness with sustainable management (again, see Appendix 1, Table 1). Green competitiveness embraces such facets as Energy consumption and energy-saving competitiveness, Ecological environment competitiveness (environmental protection), Natural resources competitiveness, Infrastructure, construction, and innovation competitiveness, Economic and socially sustainable competitiveness, or the Human Resources competitiveness.

2.1. Selection of mixed theories supporting the model of green management in the context of competition

After discussing facets of green competitiveness, we want to switch our attention to the green management which is structured into a model that could be used as a tool for the transition towards the newly perceived competitiveness in the financial sector.

In order to develop a scientifically grounded green management model, we use the Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-SCR) approach. We focus on such terms as green environmental management, green innovation, research & development management, green socio-economic management, and green human resources management.

Hence, scholars investigated when and how multinational corporations incorporate sustainability and CSR principles into their business strategy (e.g. Belen & Nuria, 2017; Strielkowski et al., 2021b). The value of the intellectual capital has been highlighted in recent international literature, particularly in the research on the small and medium-sized enterprises, because they have intangible assets as a foundation for their competitiveness constituting a core element of the organizational performance (Moskalenko and Yevsieieva, 2015; Vinícius et al., 2020).

Many researchers attempted to employ the management theories that defined the intersection of sustainability and green competitiveness. The Transition theory (Huguenin and Jeannerat, 2017) defines the challenges and the scope of a general shift, while the innovation theory is also instrumental from the theoretical and practical point of view for the critical resource recognition. Resource-based view (RBV) (Kodama, 2017), Porter's Competitiveness theory (Dess & Davis, 1984; Bezerra et al., 2018), Dynamic Capabilities theory (e.g. Bleady et al., 2018), have extensively mentioned sustainable management for green competitiveness. Stakeholder theory provides an important ground for building green management model (Kennedy & Fess, 2009; Dubey et al., 2017; Nevárez & Féliz, 2019; Nasr et al., 2020). Many theories of social responsibility such as Corporate Citizen theory, Corporate Social Performance theory, or the Shareholder value theory are among those closely related to the Stakeholder theory. These theories take various approaches ranging from the viewpoint that the company's social responsibility is only in achieving

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economic benefits and its commitment is only to the shareholders, to the theory of Corporate Citizenship which postulates that any organization has rights and obligations towards society and is most relevant in this investigation.

But how could these traditional theories help in the modern green shift from the traditional competitiveness theories to the green competitiveness theories? Since it is a must to follow the green shift, it is also essential now to create models that help the enterprises to define their strengths and weakness and to have a guide for knowing how to gain a green competitive advantage.

The traditional strategic management of a company should be focused on either a low-cost strategy or a differentiation strategy. The management theories linked to green competitiveness based on the recent literature review were not only RBV theory, alas, Contingency theory and Administrative management theory, but also some others.

Based on the literature review and management theories, we build a green management model which can be instrumental for the transition towards the green financial sector in order to gain green competitiveness. The following arguments for green management model construction are highlighted.

Gaining a green competitive advantage will rely on applying a green differentiation strategy. Green differentiation strategy is a new concept inspired by the classical differentiation strategy. We claim that a company can become special when it becomes greener. Moreover, a company can gain green competitive advantages by being able to have a bigger green market share through its market expansion.

To go further, having green market share expansion means acquiring more specifically oriented stakeholders, such as green customers and green employees. Therefore, green competitiveness is gained when a company applies green management for gaining new stakeholders and expanding on the given market. This phenomenon is about acquiring green stakeholders for green market expansion. Hence, to repeat it again, that green competitiveness is closely interlinked with the green management.

Researchers have combined sustainable management and green competitiveness and defined it in the context of green competitiveness. Many authors linked sustainable management to green environmental management, while others linked it to green innovation and Research & Development management, socio-economy management, and human resources management.

As far as this study focuses on the financial sector, according to the authors of this paper, the definition of green management in the financial sector, is the intersection of three green managerial aspects: **Management of green products and services**, **Management of the green lending platform**, and **Management of green human resources** (as in Figure 2).

The definition designates green management instead of sustainable management because the exact word "sustainable" could encounter many other aspects such as social responsibility, etc. In order not to lose the loop, the main concern is the "go green" beyond the traditional social aspects. Hence, the authors of this research think thatthe definition of green competitiveness in the financial sector is be linked to sustainable management.

2.2. The importance, gap, originality, and novelty of the study

Any company can gain green competitive advantage by acquiring more green stakeholders which will eventually lead to its market expansion. It is important to distinguish the internal and external stakeholders. The selection of the external stakeholders was based on the authors' point of view about the importance of the players in the financial

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sectors. In this research, external stakeholders consist of green customers, green creditors, green suppliers, green shareholders, green governments, and green international groups.

The main focus and priority of this study is on the transition towards the newly perceived competitiveness. The financial sector does not have the privilege anymore to choose whether to be green or not because of the green national and international regulations that are increasing year after year due to the pressure of the green international bodies and green international goals such as the Sustainable Development Goals (SDGs). We believe that sooner or later the green shift will become a norm and will rule out all companies that will not adapt it. Any company should assess the competitiveness of its environmental performance in order to identify its competitive strengths and weaknesses which might help to assist the company in improving its performance.

Many researches show that the weight of the indices of sustainable management for the green competitiveness has always been a debate. Furthermore, there are two limitations of the previous studies covering the green competitiveness indices and green strategies. First, most studies assumed that competitive indices are independent of one another and not causally related. Second, in several studies, the weights of the evaluated indices were assumed to be the same (Tsai et al., 2015). The gap in the recent literature is that the question about significance of factors affecting green competitiveness via green management remains unanswered, while companies need to know which out of the three aspects related to the sustainable management concept is more significant. Moreover, very few studies considered the aspects of green management for green competitiveness based on a mix of theoretical backgrounds such as the Stakeholder theory and Resource-based View (RBV).

Surely, sustainable management leads to the green competitiveness but the question is how could a company know in what green managerial aspect should it improve the most? Should a company improve more in its green environmental management? Or should it improve in green human resources (people)? Or should it improve in green economy such as green products and services?

The question cannot be answered because we should define many points such as the investigated sector, the relationship between the independent and the dependent factors, the mix of adopted theories that supports green competitiveness, or the mix of green (sustainable) management dimensions. Many researchers have tried to measure the indices of green competitiveness and the sustainable management aspects but very few of them have studied this effect on the financial sector. Some researchers have investigated green lending in the financial sector and the sustainable banking sectors but have rarely investigated the degree of positivity between the sustainable management aspects and green competitiveness in the financial sector from the stakeholders' point of view. Theoretically speaking, many researchers have investigated gaining a competitive advantage using the Resource-based View (RBV), Dynamic Capabilities, Stakeholder theory of Organisational theory, Institutional theory, Upper Echelon theory, or the Porter's Diamond and Porter's Cluster theory. In addition, few researchers have created a research tool based on these theories that could help the companies to know which green managerial dimension leads to competitive advantage as market expansion.

Following the comprehensive literature review, many unsolved have been detected, such as:
-Lack of studies that measure the degree of green managerial aspects that affects green competitiveness;
-2nd -Rare research tools that help the companies to know from which perspective the weights of aspects have been calculated;
- The weighting system related to the competitiveness index that was largely discussed but not from the green management perspective;
- Most studies focused on weighting the competitiveness index linked to the regional competitiveness index but not to the green competitiveness index (Vasylchak and Halachenko, 2016; Niño-Amézquita et al., 2017; Fursov et al., 2018);

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-Few studies focused on the internal green competitiveness weighting system that can help the enterprise analyse its positioning regarding green competitive advantages.

In the authors' opinion and based on conducted literature review the following solutions have to be found:
1st - Redefining green competitiveness in the financial sector;
2nd - A model that helps the companies to know from which perspective the weights of aspects have been calculated;
3rd - Weighting the degree of green managerial aspects that affects green competitiveness.

3. The objective and object of the research

All in all, main objectives of this research are the following:
In the theoretical layer, the goal of this study is to find out which management theory is the most reliable in defining the intersection of management theories, sustainability, and the green competitiveness. Therefore, a new interpretation has to be presented covering all the sustainability aspects in the financial sector: people, economy, and the environment.

In the comprehensive layer, the second goal is to determine and study the most important factors that affect the organization's green competitiveness and to build a model of green management in the financial sector.

In the practical layer, the recent research emphasizes the role of green management in the banking sector to reach green competitiveness in the short run and sustain green competitiveness in the long run.

Thence, this study aims to explore the context of sustainable management for green competitiveness:

- The effect of green management on stakeholders' green decision-making.
- The effect of green decision-making on gaining green competitive advantages.
- The shift from the traditional management towards green management in the financial sector.
- The weight of the aspects of sustainable management for green competitiveness in the financial sector.

The novelty of the research will be a novel own research tool that could be used for weighting green managerial aspects from the external stakeholders' point of view. The creation of this tool will be based on the following logic grounded on the on the recent literature review and the theories listed above:

- Identifying the green managerial aspects related to the financial sector.
- Identifying the dependent factors related to green management in the context of competitiveness.

Practically, this research tool will help the financial sector to weigh its green managerial aspects.

4. Model of transition towards green financial sector for gaining green competitiveness

In order to explore the green competitiveness and green management in the financial sector, the authors adopted Preferred Reporting Items for Systematic reviews and Meta-Analyses for Scoping Reviews (PRISMA-SCR) with a purpose to develop a greater understanding of relevant terminology, core concepts, and key items to report for scoping reviews. In the first phase, it was necessary to redefine the concept of green competitiveness in the context of green management. In the second phase, the authors reselected the best theories supporting the model of green management in the context of competition. Regarding the redefinition of green competitiveness, the most selected factors defining green competitiveness and sustainable management were selected and filtered according to the authors' point of view (see Appendix 1). In the second phase, the authors reselected the best theories supporting the model of green management in the context of competition based on the recent literature review (see Appendix 2). The authors obtained the data from such databases as WOS, KJD, RSCI, and SCIELO for the timespan equal to the last 5 years (2015–2020) in English language.

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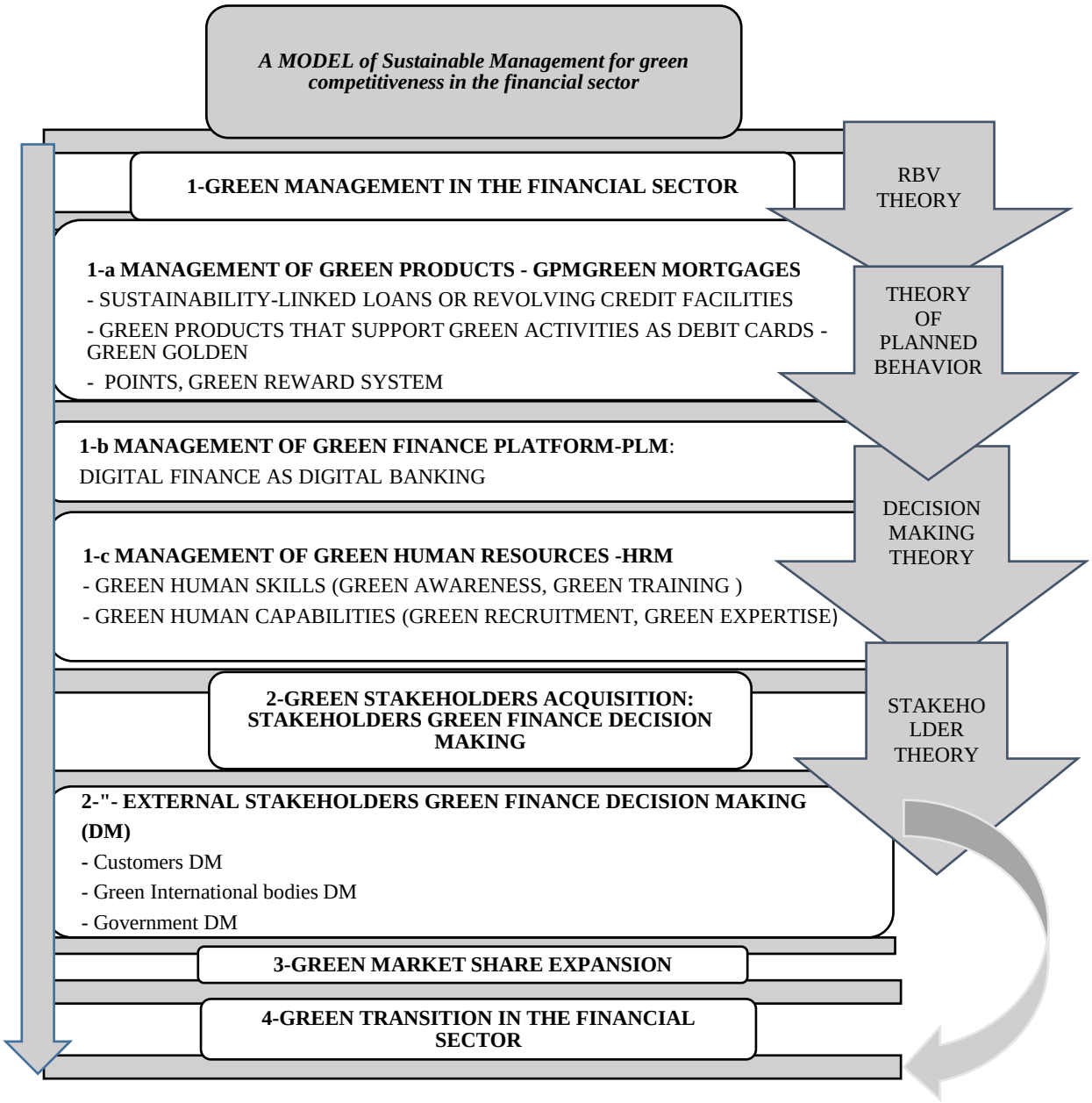

Figure 3. The map of the green management in the financial sector
Source: created by the authors

This study aims to assess two main relationships in the Mena Region banking sector:

1) The relationship between Green Management (GM) dimensions in the financial sector which characterizes the independent variables which consists of A-Management of green products in the financial sector, B-Management of green platform in the financial sector, and C-Management of green human resources in the financial sector. The external stakeholders' green decision-making characterizes the dependent variable which consists of green customers, international green bodies, and green government.

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2) The relationship between GM aspects in the financial sector and the green market share expansion leads to a green transition in the financial sector.

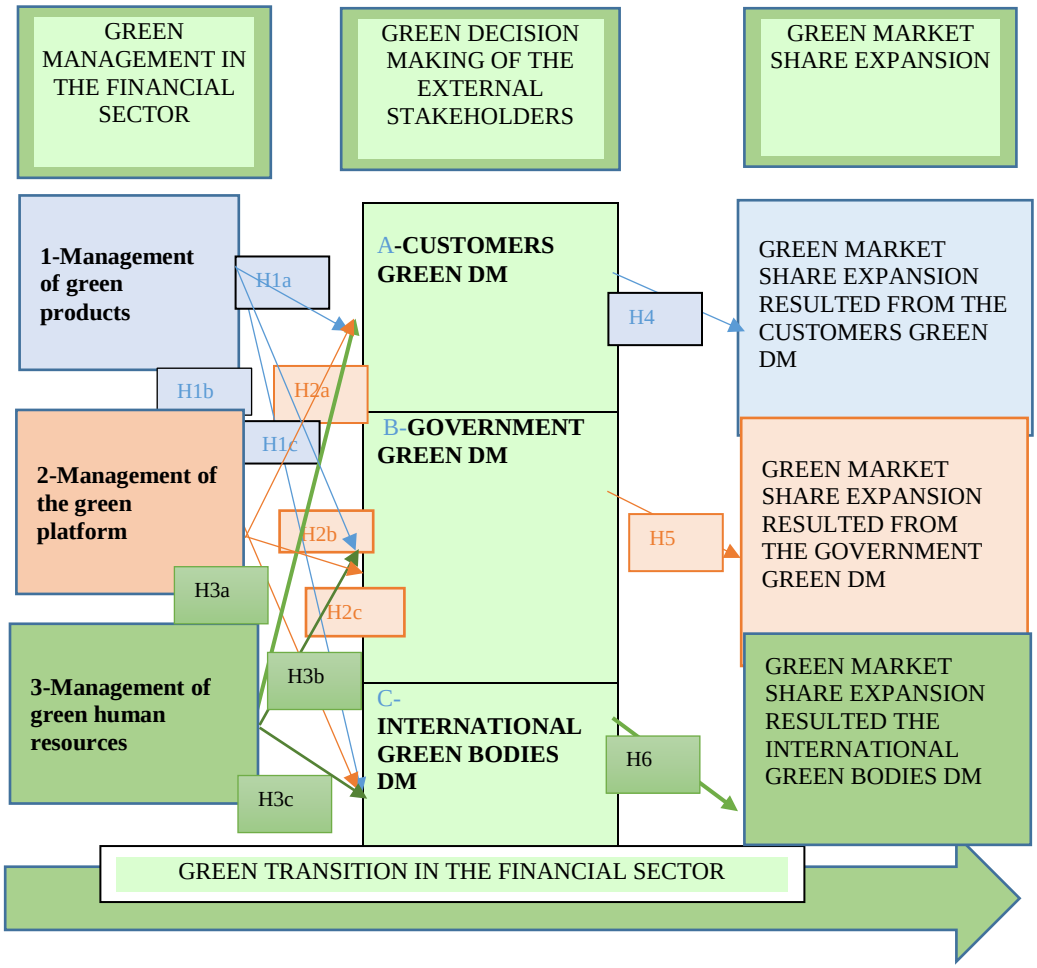

Figure 4. Hypotheses' model–Green transition in the financial sector
Source: Created by the authors, where:

1) H1a-The degree of influence of the management of green products on Decision making of the customers.
   H1b-The degree of influence of the management of green products on Decision making of the government
   H1c-The degree of influence of the management of green products on Decision making of the international green bodies.
2) H2a-The degree of influence of Management of the green platform on Decision making of the customers.
   H2b-The degree of influence of Management of the green platform on Decision making of the government.
   H2c-The degree of influence of Management of the green platform on Decision making of the international green bodies.
3) H3a-The degree of influence of Management of green Human resources management on Decision making of the customers.
   H3b-The degree of influence of Management of green Human resources management on Decision making of the government.
   H3c-The degree of influence of Management of green Human resources management on Decision making of the international green bodies.

In other words, this study investigates the degree to which the decision-making of the external stakeholders is affected by the management of green products and services, the management of the green platform, and the management of green human resources in the financial sector.

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It should be noted that in this model, DM represents the decision-making of the external stakeholders, and DM1 is the decision-making of the customer. DM2 is for the decision-making of the government; DM3 is for the decision-making of the green international bodies. The Degree of DM1 affected by A, B, and C:

DM1 is highly strong-strongly-neutrally-slightly-negatively affected by A, B, and C.
DM2 is highly strong-strongly-neutrally-slightly-negatively affected by A, B, and C.
DM3 is highly strong-strongly-neutrally-slightly-negatively affected by A, B, and C.

H1a- the Decision making of the customers is positively influenced by the management of green products/services.
H1b-The Decision making of the government customers is positively influenced by the management of green products/services.
H1c-The Decision making of the international green bodies customers is positively influenced by the application of the management of green products/services.
H2a-The Decision making of the customers is positively influenced by the Management of the green platform.
H2b-The Decision making of the government is positively influenced by the Management of the green platform.
H2c-The Decision making of the international green bodies is positively influenced by the Management of the green platform.
H3a-The Decision making of the customers is positively influenced by the Management of green Human resources management
H3b-The Decision making of the government is positively influenced by the Management of green Human resources management
H3c-The Decision making of the international green bodies is positively influenced by the Management of green Human resources management
H4-DM1 Customers' decision-making positively influences the market share expansion.
H5-DM2 Government decision-making positively influences the market share expansion.
H6-DM3 External green bodies' decision-making positively influences the market share expansion.

The degree of relationship is the following: DM is highly strong-strongly-neutrally-slightly-negatively affected by A, B, and C. the questions are based on a five-point Likert-scales ranging from "1" meaning "strongly disagree" to "5" meaning "strongly agree". The elements used to evaluate the variables were obtained from the scientific studies. The decision-making of the external stakeholders is affected by the management of green products and services, the management of the green platform, and the management of green human resources. The key questions are: How much weight does each relationship have? Which one weighs more?

The null hypotheses assume that all the aspects are equal as follows:
- The decision-making of the customer is positively affected by the management of green products and services, by the management of the green platform, and by the management of the green human resources.
- The decision-making of the government is positively affected by the management of green products and services, by the management of the green platform, and by the management of the green human resources.
- The decision-making of the international green bodies is positively affected by the management of green products and services, by the management of the green platform, and by the management of the green human resources.
The decision-making of the external stakeholders is considered to be a dependent variable, while the green managerial aspects are considered to be the independent variables.

Knowing the degree to which the green managerial aspect affects the decision making provide us with a tool for weighting green competitiveness.
A-The management of green products and services in the financial sector (GFP) is assessed through:
- Green mortgages;
- Sustainability-linked loans or revolving credit facilities;
- Green products that support green activities such as debit cards - green golden points - green reward systems.
B-Green finance platform (GFPL) is assessed through digital finance as the digital banking.
C-Green human resources management (GFHR) is assessed through green human skills (green awareness-green training) and green human capabilities (green recruitment - green expertise).

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The relationship degrees will positively or negatively affect the external stakeholders' green finance decision-making (DM) which is assessed by the customers' decision making (CDM), government decision-making (GDM), and green international bodies decision-making (IDM). The strongest obtained degree results in the highest green competitiveness degree a financial company will gain. The lowest obtained degree represents the lowest green competitiveness degree a financial company will gain.

Conclusions

Building a research model where the dimensions of green finance are elaborated in the context of green competitiveness will be the basis for the future research conducted by financial companies. The strength or weakness of the managerial aspects will provide the financial companies with a better orientation regarding how to shift for greener finance.

Switching to greener finance needs a green managerial decision in order to know exactly where to enhance and where to focus for gaining green market share and subsequently gaining green competitive advantages.

Weighting the green competitiveness gives a sense of direction to the financial companies and lets them know more about the green managerial structure and the green competitiveness structure of the company.

This study has evaluated the green financial dimensions based on both theoretical and practical perspectives which will be a good reference for further studies and a base for statistical tests done in the future by the financial companies and scientists alike.

Limitations

This study has the following limitations: First of all, the internal stakeholders as green employees, green managers, and green stockholders were excluded. It is recommendable to study the internal stakeholders in further research where the author can determine the impact of green management on internal stakeholders' decision-making. This model may not fit all the sectors because the authors cannot generate the result of a specific sector as the financial sector to other sectors as agricultural sectors.

Another limitation is that the authors focused on the external stakeholders only and excluded the internal stakeholders. Weighting the degree of green managerial aspects were limited to a geographical area which is the Middle East. Thence, another study covering larger or other geographical area might be necessary for providing better accuracy.

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Appendix 1

Table 1. Facets of green competitiveness and their interrelation with green management

The spectrum of green competitiveness	1-Energy consumption and energy-saving competitiveness+ 3-Ecological environment competitiveness (environmental protection) 5-Natural resources competitiveness		2-Infrastructure, construction, and innovation Competitiveness-	4-Economic and socially sustainable competitiveness	6-Employees' skills –Human Resources competitiveness
Green management	a=1+3+5 Green environmental management		b=2/ Green innovation research & development management	c=4/Green socio-economy management	d=6/ Green human resources management
Fu et al., 2017a	1	green environmental management	Wang et al. 2016	3	green environmental management
Fu et al., 2017a	1	green environmental management	Cheng et al., 2018	3	green environmental management
Fu et al., 2017a	1	green environmental management	Cheng et al., 2018	3	green environmental management
Guo, & Zhanwen, 2017	1 5	green environmental management			
Tsai et al., 2015	1 5	green environmental management	Cheng et al., 2019	3	green environmental management
Tsai et al., 2015	1 5	green environmental management	Cheng et al., 2019	3	green environmental management
Tsai et al., 2015	1 5	green environmental management	Cheng et al., 2019	3	green environmental management
Tsai et al., 2015	1 5	green environmental management	Cheng et al., 2019	3	green environmental management
Fu et al., 2017a	1	green environmental management	Cheng et al., 2019	3	green environmental management
Fu et al., 2017a	1	green environmental management	Konuk et al., 2015	3	green environmental management
Fu et al., 2017a	1	green environmental management	Konuk et al., 2015	3	green environmental management
Guo, & Zhanwen, 2017	1 5	green environmental management	Cheng et al., 2018	2	green innovation and research

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					&development management
Cheng et al., 2018	2	green innovation and research &development management	Abdolvand et al. 2017	4	green socio-economic management
Fu et al., 2017a	2	green innovation and research &development management	Abdolvand et al., 2017	5-4	green socio-economic management
Barysienė et al., 2015	2	green innovation and research &development management	Maitre et al., 2018	4	green socio-economic management
Barysienė et al., 2015	2	green innovation and research &development management	Maitre et al., 2018	4	green socio-economic management
Abdolvand et al., 2017	4	green socio-economic management	Maitre et al., 2018	4	green socio-economic management
Abdolvand et al., 2017	4	green socio-economic management	Maitre et al., 2018	4	green socio-economic management
Abdolvand et al., 2017	4	green socio-economic management	WESO Greening with Jobs, n.d.	6	green human resources management
Lin & Chen, 2017	6	green human resources management	WESO Greening with jobs, n.d.	6	green human resources management
Lin & Chen, 2017	6	green human resources management	Lin & Chen, 2017	6	green human resources management
Mishra, n.d. 2016	6	green human resources management	Lin & Chen, 2017	6	green human resources management

Source: created by the authors

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Appendix 2

Table 2. Management theory detection based on the PRISMA diagram.

Management (MNG) theories	TS= (Systems Management and Theories*) +	(Sustainable* Management) =266 results	+(Competitiveness*) =10 results	MNG theories +Sustainable Management +Competitiveness
1184 Management theories (100%)	All systems management theories	266 (46%)	10	=23
Competitiveness 146 (12%)	Contingency management theory	42	3	10 competitiveness – specified systems management theories
Sustainable management (SM) 574 (48%)	Theory X &Y	6	1	13 other management theories
Undetected management theories =308 (54%)	Administrative theory	110	1	
Detected SM theories=266 results (46%)	Bureaucratic theory	8	1	
	Human relations theory	73	1	
	Douglas theory	7	0	
	Mixed systems Management theories	20	31	

Source: created by the authors

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SMALL STATES, STATESCRAFT AND THE CHALLENGES OF NATIONAL SECURITY: THE CASE OF GUYANA

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Abstract. Small states all over the globe have peculiar challenges foisted on them by their meagre population which may make some unviable and inconsequential in the comity of nations. While this can be said to be normatively politically correct, the realities have proven otherwise. Countries like Singapore, Qatar, Oman, Switzerland, etc., have crafted enviable statecraft that positioned them in strategic socio-economic and political vantage positions. For the Caribbean country of the Cooperative Republic of Guyana, the quest to succeed as a strong and virile small state has remained daunting due to a lot of intervening internal and external dynamics. This study is therefore poised to evaluate the Guyanese national trajectory towards a sustainable and stable Caribbean nation in the face of precarious post-colonial history, political alliance and nuances of intra and inter-regional influences on a country with great economic and geo-strategic potentials and the contradictions of a small population. In achieving this, the study relied on historical research design which is qualitative and explorative in nature. Study therefore relied extensively on secondary source of data via literature survey of books, reports from dailies and periodicals, government official publications, conference papers, journal publications and internet sources. Study also proffers policy options that can ameliorate the Guyanese post-colonial political challenges occasioned by the precarious colonial experiences, internal and external security challenges.

Keywords: Challenges; Small States; Statecraft; National Security; Caribbean Countries; Guyana

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Introduction

Like every other pre-colonial societies of Asia, Africa, and Latin America, Guyana has unique and complex historical foundations and several transformations from the pre-colonial to colonial and from the colonial to post-colonial albeit postmodern societies. The country known today as Cooperative Republic of Guyana (CRG) located at the northern corner of South America (see Figure 1) derived its name prior to European settlement from the name of the land "Guiana" which means the "Land of water" and that which in its present day reflects its British and Dutch colonial past, and is the only English speaking country of South America (Bonham, 2020). Ethnically, the country is presently a multiracial society with the people of India, Africa, Portuguese and Chinese descents. The Afro-Guyanese are said to account for 33% of the country's population, while the Amerindian account for 8% and mixed of the white and other groups account for 11% of the total population of the country (Guyana Development Policy Review, 2003:1).

Figure 1. Location of Cooperative Republic of Guyana (CRG)
*Source***:** CIA World Fact Book

The country was discovered in 1498 by the Europeans centuries ago but gained her independence on 26 May, 1966 from the United Kingdom as a dominion, and a republic on 23 February, 1970.The nation which is considered part of the region of the Caribbean is surrounded by the Atlantic Ocean to the north, Brazil to the south and southwest, Venezuela to the west and Suriname to the east making it one of the smallest sovereign states on the mainland of Southern America after Uruguay and Suriname. It is also a member of the Commonwealth of Nations as part of her historical British heritage. The history of the nation is characterised by several battles ranging from internal migration to the battle for supremacy and possessions by foreign invaders of the Spanish, French, Dutch and Britain origins (Wells, 1990; Odeen, 2009).

The earlier settlers were believed to be the nomads from Asia about 35,000 years ago and who later became the Carib tribe and the first settlers at the interior end of the ancient nation. There are also the Arawak tribe located

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along the Coast. Both ancient tribes of Guyana were believed to have their origin traced to South America having migrated to the South American hinterland and to the present-day Guiana and in the Caribbean islands. It was also believed that these migrants met the Alonso de Ojeda's first expedition from Spain in 1499 at the Essequibo River. The ancient society of Guyana was believed to be dominated by the nomads who gradually migrated from the Central and South America before the experiences following Christopher Columbus's voyages changed their pattern of behaviour (Frank van de, 2013).

While the Arawak were mainly farmers, hunters and fishermen settlers along the Caribbean islands, the warlike migrants of the bellicose Carib from Southern America moved towards the interior and altered the tranquillity of the Arawak society on arrival. The warlike behaviour of the Carib made them displace the Arawak throughout the islands of the Lesser Antilles – a group of islands in the Caribbean Sea. Following Christopher Columbus discovery of the Arawak settlers, the Spanish moved in to explore the settlers who were easier to conquer than the warlike Carib tribe who fought back and resisted the invasion of the intruders to maintain their independence. This period marked the origin of the consolidation of colonial empire in the ancient region with the Dutch (the Netherlands) as the first Europeans to settle in the modern day Guyana after her independence from Spain in the late 16th and early 17th centuries and had emerged as the major commercial power and traders with the English and French colonies in the lesser Antilles (Hirsch, 1977; Brereton, 2004; Frank van de, 2013).

Following the 1899 ruling of an international tribunal, the land of Guyana which is a country on the northern mainland of South America and considered part of the Caribbean because of its strong culture, historical and political ties with other Caribbean countries was awarded officially to Great Britain (Wells, 1990). The post-independence state of the CRG also has its remarkable history and origin which started in 1814 as a British colonial territory, but gained her independence in 1966 but became a republic in 1970. During the period of colonial rule to the early years of post-colonial era, agriculture and mining were the major enterprises of the people, though controlled by two British companies: Booker McConnell and Jessel Securities both of which also controlled the largest sugar estates until the 1970s. By the early 1980s, the new government of the Republic of Guyana had completely taken charge of the control of the nation's resources and administration (U.S Library of Congress, 1991).

Fundamentally, the post-independent state of the Cooperative Republic of Guyana is structured along parliamentary democracy with a constitution, a National Assembly, a multiparty system, elections, and a president chosen by the majority party, a minority leader, and a judicial system that is based on common law like any other democratic states in the world. The republic has often witnessed several statecraft challenges and some of which were complicated by the emerging natural resource wealth including crude oil resources. As a consequence, the nations' foreign policy posture has always been influenced by these national problems since its independence (Tim, 1992).

According to Ellis (2019) the new oil wealth has provided the republic (CRG) an enviable status within the nations of the Caribbean and among the comity of nations despite the emerging challenges occasioned by the seemingly regular internally and externally induced challenges in the form of domestic political unrest, as well as criminal activities such as human trafficking, money laundering, production of narcotic substances and trafficking, illegal timber extraction and mining related offences, cum external challenges of its territorial borders and sovereignty by its neighbouring Venezuela and Suriname (Ellis, n.d). The inability of the government of the republic to respond adequately to these daunting challenges has impeded the progress of the state and has also deprived the state the expected admiration from its citizens and the international community as a whole in recent times.

Over the years, a lot has gone wrong with the within the ambit of statecraft in the republic following the government inability to contain the country's domestic challenges in its post-independence era. Essentially, the

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challenges of statecraft have been linked to the state's post-independence political experiences, leadership skill and diplomacy. The national goal of contemporary state of CRG has been in the hands of who manages the affairs of the state, his powers and positions as well as policies towards the neighbouring states of the Caribbean.

The Nature of the Problem

Small states all over the globe have peculiar challenges foisted on them by their meagre population which may make them unviable and inconsequential in the comity of nations. While this can be said to be normatively political correct, the realities on ground have proven otherwise. Countries like Singapore, Qatar, Oman and Switzerland etc have crafted enviable statecraft that positioned them in strategic socio-economic and political vantage positions. For the Caribbean country of the Cooperative Republic of Guyana, the quest to succeed as a strong and virile small state has remained daunting due to a lot of intervening internal and external dynamics. The unanimous hypothesis of the inherent deficiencies of small states as endemically prone to limited capabilities and potentials in the spheres of the economy, politics, governance and security have remained sustained .

Analysts and researchers have identified the subjective perception of small states as weak and incapable of mustering a formidable military capabilities, making them vulnerable to attacks and intimidation by bullying neighbours or regional hegemonic powers. As a corollary to the above, the apparent extensive reliance of small states on trade in the face of limited exports, finance and human resources remains a viable recurring decimal.. This reality is an anathema to strong international trade negotiations amongst nations where economic virility is a sine qua non in advantageous trade relationships. This is the prevailing global reality even among large nations.
Consequently, the Cooperative Republic of Guyana (CRG) with an interesting colonial and postcolonial history enmeshed in the vicissitudes of the contradictions of development has been providentially blessed with a new wave of petro-wealth and an incredible positive economic growth trajectory that should be properly managed. It is therefore pertinent that this great opportunity be optimally utilised. As a wasting asset, oil wealth has remain an Achilles heel in a lot of development countries in South America and indeed Sub Saharan Africa and the Middle East. The lessons therefrom should be adequate for sustainable public policy in Guyana.

The Caribbean region and indeed Guyana has in the recent years been battling with challenges of governance-delivery of basic services, criminal violence and endemic corruption. In the same vein, increased migration, rising populism and the deficit in the support for democratic rule in the Caribbean albeit Guyana has dampened the expectations of citizens from the government.

These inherent vulnerabilities of small states accentuated by the impregnable forces of globalisation and regional hegemonic powers naturally predisposes the Cooperative Republic of Guyana to reposition herself within the CARICOM platform and indeed other global multinational institutions to achieve her state policies. This step will help create a sustainable buffer from the onslaught of real threats to Guyana sovereignty and the whole gamut of human security in the country.

Generally, a number of small states have emerged outside what can be tagged with the descriptive taxonomy like those from Asia, Africa, Latin America and some of the Middle East that neither belong to the First World or the Western Industrialised Nations of Western Europe, USA, Japan nor of the bloc of the Second World which include the former Communist nations of the former Soviet Union and those of the Eastern Europe (Handelman, 2001). Undeniably, these small states have historical commonalities and experiences as well as internal security challenges such as slavery, colonialism, low Gross Domestic Product (GDP), high unequal income distribution, poor infrastructures, high level of illiteracy, low level of unemployment, high birth rate, high death rate, systemic corruption, unstable economic and political environment, and rural-urban inequalities (Audu, Ologbenla, Anifowose & Abdul-Rahoof, 2013). Unfortunately, the CRG in its post-independence era like some of its Third

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World counterparts from Asia and Africa has witnessed diverse internal and external national issues that seem to have impeded its internal statecraft and socio-political and economic developments.

Despite these ugly and emerging situations confronting the state of Guyana, the government seems to lack the capability to resolve them to the admiration of its citizens and the international community, thus, attracting attention to state's internal affairs in recent times. The obvious dichotomy between the big states of Western Europe, USA, Japan, etc., and the small states of underdeveloped nations or the Third World Countries or the global south, particularly the small states of the Caribbean have manifested itself in the Guyana's case that has been consumed by a sheer governments' ineptitude to contain internal challenges confronting the nations of the global south. This circumstance, undeniably, requires urgent or immediate explanations and attentions by the government of the CRG.

Apart from the common challenges confronting the state of Guyana, its meagre population, geo-strategic location and external dynamics have also consistently affected the level of relations between the country and its immediate neighbours and at the same time made the country apparently unenviable within the comity of nations. Essentially, while some states within the global south have proven otherwise by designing and implementing enviable robust statecraft template that has placed them in strategic socio-economic and political vantage positions in the international system, Guyana is yet to key into this progressive paradigm. The entire business of statecraft in the republic of Guyana remained largely as a resulting of choking internal and external existential human security challenges confronting the country.

The country has a lot to learn and adopt from viable and strong states like Singapore, Qatar, Oman, and Switzerland and significant others which have continue to remain strong, virile and geo-strategically relevant in global affairs. The conduct of state affairs (statecraft) in the country's post-independence era, thus, has been seriously impeded by internal challenges or domestic issues emanating from a polarised political environment cum ethnic rivalries between the two major tribes of India and African descents. The 21 December, 2018 political crisis between the Guyana's principal opposition political parties of the People's Progressive Party (PPP) dominated by the Guyanese of Indian descent successfully passed a vote of no-confidence against the coalition government jointly formed by A Party for National Unity (APNU) and the People's National Party, the core party dominated by Guyanese of African descent, and the Alliance for Change (AFC), and the subsequent mass defections of members of the AFC to the other party has also impeded the smooth conduct of statecraft in the country (Ellis, 2019). This spectacular political incident resurrected the ethnic rivalry that was already blossoming in the country's socio-political landscape, it has been identified by analysts and observers alike, as one of its greatest domestic challenges in recent times.

Furthermore, Granger (2009), Neuman (2013), The Guardian (2015) and Bebi (2018) cited in Ellis (2019) have argued that the Guyanese government have been confronted by critical challenges that have threatened the country's national security as well as its sovereignty over the years. The internal challenges emanating from mining related criminal activities, money laundering, illegal extraction of timbers, human and narcotic trafficking, and a host of other criminal activities within the national border of the country have been identified as critical challenges confronting national statecraft in the republic. The external threat emanating of the continued pursuit of Guyana's territory along the Essequibo River in the Eastern part of the country cum the threat of the claims of two Guyana's offshore Exclusive Zone which is the source of Guyana's new oil wealth along the maritime border close to the sea, are also identified as problems confronting the government of the republic in recent time (Ellis, 2019).

Also identified as critical problems confronting statecraft in Guyana is the Surinamese government interference in the Guyanese territorial border along the eastern end of the country, as well as Suriname's continuous claims of the remote and sparsely populated portion of Guyanese land located at the interior end of the New River Triangle.

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The May 2018 incident which took the lives of 16 Guyanese fishermen alleged to have been killed by Surinamese pirates seen as reprisal attacks for the prior killing of a Surinamese drug Lord, also poses exponential threat to Guyana's national security and has remained a potent threat that is likely to repeat itself in the future if not properly managed (Bebi, 2018). The plethora of challenges confronting the Guyanese government and the government inability to contain these national issues or challenges have undeniably bedevilled the state's foreign policy posture and other sundry external diplomacies, and most consequentially, making statecraft a very difficult task for the Guyanese national government in recent times. There are, however, several academic debates relating to the major reasons behind these disturbances confronting the country over the years, why the successive governments have not been able to contain the internally and externally induced perturbing challenges, as well as the best policy alternatives or options to that could resolve these national security problems confronting the state of CRG. This study therefore is poised to examine the causative factors or the reasons for the security challenges confronting the CRG, a small state in the Caribbean, and to offer the best policy options to resolve these internal security problems in the over the years.

Objectives of the Study

The broad objective of this discourse is to examine the link between the challenges of statecraft in small states with a focus on the Republic of Guyana. While the specific objectives are to:

1. Identify the root causes of the internally induced or domestic challenges in the Cooperative Republic of Guyana and their impact on the country's post-independence statecraft,
2. Identify the externally induced national challenges confronting the country and their impacts on the post-independence statecraft, and
3. Ascertain the similarity in forms and characters of the national challenges in the CRG and the other Small states of the Caribbean,
4. Ascertain the extent to which the government has been able to manage these internal challenges over the years, and
5. Proffer policy options to these challenges of statecraft in the CRG.

Research Questions

The study seeks to answer the following research questions:

1. What are the root causes of Guyana's domestic challenges and their impacts on the country's post-independence statecraft?
2. What are the externally induced challenges and their impacts on the country's statecraft over the years?
3. What are the similarities in forms and characters of the Guyanese national challenges and those of the other small states in the Caribbean?
4. What are the efforts made by the CRG government to manage these internal challenges over the years?
5. What are the best policy options to the challenges of statecraft in the CRG?

Method of the Study

Considering the nature of this study, the historical design of research which is qualitative and explorative in nature was adopted. For the Caribbean country of the CRG, the quest to succeed as a strong and virile small state has remained daunting due to a lot of intervening internal and external dynamics. This study, therefore, relied on secondary source of data via survey of books, government official documents and periodicals as well as journal publications and internet materials to evaluate the Guyanese national trajectory towards a sustainable and stable Caribbean nation in the face of precarious post-colonial history, political alliance and nuances of intra and

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inter-regional influences on a country with great economic and geo-strategic potentials and the contradictions of a small population.

Review of Related Literature

The Concepts of Small States versus Big States

The crisis of underdevelopment and dependency plaguing the *Small states*, often identified among the Third World Countries (TWCs), particularly those located in the Caribbean islands of the continent of Southern America, and their post-independence challenges, motivated and attracted the attention of social scientists as well as the dependency and modernisation theorists alike, to understand the nature, reasons or causes of the dependency status of the Small states of the TWCs on the Big states (or the Developed countries); and by extension, the division of the world into two major blocs of the global south and the global north respectively.
Apparently, the division of the nations of world into blocs prompted scholars to attempt to provide clarification between the concepts of *Small states* from the global South, and *Big states* from the global North respectively. Historically, the disintegration of European colonial empires in Africa, Asia and South America, as well as the demise of communism following the collapse of the Soviet Union albeit Cold war in the early 1990s, undeniably, provided opportunities for the emergence of new states in the global world, and some of which are today striving to find their footings in the comity of nations despite their rich natural resources.

These circumstances inextricably created confusions among the scholars as to what actually small states are, and the circumstances that led to the division of the world into *Small* and *Big States*. There are immense debates over the past years on how best to define a Small state and to also have clear conceptual discernment of the concept of *Small states* and the *Big states*. In this regard as part of the scholarly debate, Peya and Jo-Ansie (2017:119) citing Prasad (2009) argued that "there is actually no single definition of the concept of Small states because the variables for determining small states are still evolving, thus, it is difficult to provide a generally accepted definition of the concept". To this end, they defined small state in terms of its "size, the size of its population, small territorial size, economic strength or weakness, a state's perception of itself as a small state, and a low level of involvement in global affairs".

The Commonwealth and World Bank (2000) defined Small state in terms of its territorial size, the size of the state's economy (low income), and population (8 million people and less). Archer, Bailes and Wivel (2014) cited in Vaicekauskaitė (2017:8) see Small states as those states that were not *great powers* neither were they *Second world countries*, but were those too weak to make any significant difference in the international order nor impacted any remarkable changes on the rules of the global system. For Jacque (1971) also cited in Vaicekauskaitė (2017) small states are those states that are "neither on the global nor regional scales and are unable to impose their political wills or protects their national interests among the comity of nations by exerting much of power politics, as well as unable to defend their national interests by exerting both political, economic and military powers".

Bailes (2010) cited by Baldacchino (2012:15) sees the term from what characterises it as a small state such as "a shortage or lack of certain normal attributes of state power, autonomy and international standing among the comity of nations". The obvious fact about the plethora of definitions of *Small states* above is that emphasis was based on material factors, such as the size of the state, and by implication, the population of the states. There are also emphasis on the capabilities of states' foreign policy behaviours, military powers, strategic environment and historical organisation in the global system (Wivel, 2014; Jurkynas, 2014).

In the same vein, the definitions of small states above reflect the actual conceptions of what small states are. There are also obvious flaws or defects in the definitions above because the definitions failed to put into considerations the levels of developments recorded in some of the emerging economies like Switzerland and the

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BRICS nations of Brazil, Russia, India, China and South Africa, as well as the Asia-Tigers-Taiwan, Singapore and South Korea, and significant other from the Middle East such as the UAE, Qatar, Oman, etc., and that share the same characteristics and faith with the supposed small states on the one hand, and a reasonable economic and political greatness with the big states over the years on the other hand. These obvious analytical lapses in the conceptual delineation of small states by scholars tend to open a flurry of endless debates that would take time to end with a unanimous agreement on the categorization of small states by the academic community.

On the contrary, *big states* are conceived differently from small state since they share improved indices or opposite features or characteristics. By and large, they are the states that enjoy all that the small states are denied because of the circumstances surrounding their emergence as nation-states in the global system. Such indices of determining a big state include large population, large territories, extended foreign policy behaviour, large and industrialised economy, political and military power, among other factors. Big states are often found in the global North or what is generally refers to as the developed nations of the world or capitalists economies or industrialised countries of Western Europe, some of the Eastern Europe, USA, Japan, etc.

In recent times, *big states* of the world system are the super powers of Western Europe who were at a time the colonisers of the some of the so-called small states or of the states of the global South including Asia, Africa and Latin America. They are states of the international system that enjoy economic autonomies and interdependent economies. By implication, their foreign policy behaviours are based on self-actualisation. Generally, internally and externally induced challenges have been the major challenges confronting the small states of the global south or TWCs including the states of the Caribbean in their post-independence era. Statecraft which is the art of the conduct of government affairs has been a mirage in some of the new and small states of the global south, particularly those of the Caribbean, including Cooperative Republic of Guyana. To this end, having a concise or generally accepted definition of the term has been a difficult task for scholar.

Empirical Review

Guyana and the Root Causes of its Domestic Challenges and their Impacts on Statecraft

Undeniably, a lot goes with the conduct of state affairs or what is termed the practice of statecraft in our contemporary societies. States' political experiences, leadership skills and capabilities, as well as foreign policy and diplomatic posture are essential tools of statecraft. The goal of any nation-state, thus, depends on how it manages its domestic and external relations, all of which are imbedded on the conduct of state affairs. Veritable statecraft in the state of Guyana has been under immense threat following persistent centripetal forces against all manners of confrontations in its domestic front, and that which ranges from climate change to socio-cultural, economic and political challenges.

All of these factors have been synonymous or associated with the state of Guyana. Significantly, the geographical location and the relatively small size of the country's population which is estimated to be under a million and has about 60% of essentially rural populace have been identified as one of the inhibiting factors to its development since independence. Essentially, over 80% of the Cooperative Republic of Guyana's Gross Domestic Product (GDP) including its agricultural production and other non-mining sectors' activity are concentrated in the coastal area with low sea level. This has over the years attracted government's persistent protection of the country from the sea and other forms of climatic infractions. With the country's major export commodities as sugar, rice, timber, fishery, textile, bauxite and gold mining, it is yet to find its footings among the comity of nations (FAO/World Bank Cooperative Programme, 2005).

Also identified as a challenge, is the country's multi-racial community comprising generations of Indian, Asia, African and Portuguese descent on the one hand, and the indigenous tribes of the Carib – a scion of Asian nomads and the Arawak tribe both of which origins were traced to South America, on the other hand (Guyana

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Development Policy Report, 2003; Ellis, 2019). This variegated demographic mix has remained a major challenge to national development in the face of internal and external political manipulations. The lack of articulate racial integration in Guyana has continuously robbed the country the need nation building pivot need to engender patriotism and nationalistic fervour to foster sustainable development of the republic.

Guyana Development Policy Report compiled by the World Bank in 2003 and supported by other multilateral development reports in recent years indicate that the total population of the country is made up 33% Afro Guyanese and 48% of Indo Guyanese. These figures remains a subject of intense debates as some analysts believe that Afro Guyanese make up more than 40% of the country's population. What is clear however is the fact that the two dominant sub races in the country have been in perpetual inconsistent struggle for the republic's socio-economic and political power spanning decades of Guyana's political history. This perennial division has remained one of the major challenges confronting the nation's socio-political environment over the years. Policies and other developmental strides initiated by the government to promote national growth and development as well as in the fight against corruption and crime have been thwarted by some of these factors as well.

The deep inter racial and political divisions have become deeply embedded on the domestic polity of the country and remains an anathema to socio-economic development. These aforesaid factors have also impacted negatively on the mechanisms of the nation's parliamentary decision-making, and undermine its respect for the rule of law and complicated by the preference of ethnic identity over state's inequality, equity and national unity and development. Citing Singh (1996) and Ali (1997) respectively, the Guyana Development Policy Report (2003:1) states that, "upon independence, ethnic interest, relevance and dominance became the priority and practice among the dominant ethnic nationalities in the republic of Guyana". The report further stated that the two largest ethnic groups in particular jostled for economic, social and political powers, which had in no limited measure intensified the already existing multiracial consciousness among the people of the republic. The Cooperative Republic of Guyana (DRG) remains entrapped in racial identity politics and mutilated development.

With each groups struggling to gain pre-eminent advantage over the other and maintain paramountcy, the country remains in the throng of ethnic cum racial rivalry which up to date is a dominant practice in the country's political system. Ethnic, racial and primordial survival instinct and security was deemed the prevailing normal well over the economic wellbeing of the populace while national unity was equally sacrificed on the altar of ethno-racial sentiments. Over the years the dominant ethnic groups have been adopting, among other things, constitutional engineering, executive aggrandisement, parliamentary marginalisation, and boycotts of parliaments, as strategies to pursue their political agenda. All of which have impacted negatively on socio-political cohesion among the ethnic groups in the republic (Guyana Development Policy Report, 2003:1). This has engendered politics of ethno-racial patronage and institutional discriminatory policies geared towards ethnic survival rather than national survival. Here in lies the bane of Guyana's nation building and national development effort.

In the same vein, Bisram (2015) opines that the emergence of racial conflict in the Cooperative Republic of Guyana and its shifting impacts on national development, presented the country as a society plagued by intractable racial division and socio-political and economic challenges. To Bisram, the multi-ethnic state, how it started during the colonial rule, and how it was advanced by the colonial forces to serve their interests, as well as how it became institutionalised, undisputedly, became one of the reasons the United States and the United Kingdom delayed the independence of the former colony. To date, race and ethnic conflicts impacted negatively on the composition and conduct of country's socio-political and economic development despite its geo-strategic position, and abundant natural resources (Bisram, 2015). The new oil wealth may not change much of this trajectory as different global socio-economic interests are beginning to amass in the country. The eventual aggregate result of the new scramble for Guyana's oil resources remains a conjectural discourse even as scholars believe that new alliances and hybrid political economic templates will emerge amongst global powers with indeterminate developmental consequences for the republic.

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In another development, the CRG finance minister, Hon. Vinston Da Costa Jordan has identified inadequate trend in the funding of quality education and health care, as well as addressing the nation's vast infrastructure sector development and poverty reduction as great challenges of the government over the years. Also identified as a problem is the difficulty experienced in the process of integrating and harmonising the nation's multiracial differences and reduction of inequality among the ethnic groups across the country (Guyana Ministry of Finance First Voluntary National Review, 2019). By and large, ethnic assertiveness and discord among the ethnic groups has posed the greatest challenge to the nation and its overall development, including the standard of living and quality of life of the citizenry. These inter alia have also denied the country is vantage position among the states of the Caribbean and in the international community.

Guyana and Externally Induced National Security Challenges

The Cooperative Republic of Guyana's externally induced challenges have also impacted on its national sovereignty, unity and development over the years. Perhaps one of the most prominent of all the externally induced challenges is the threats emanating from the continued pursuit of Guyana's territory along the Essequibo River in the Eastern part of the country and the threat of the claims of two Guyanas' offshore Exclusive Zone, which is the source of Guyana's new oil wealth along the maritime border close to the sea, and Surinamese government interference in the Guyanese territorial border along the eastern end of the country, as well as Suriname's continuous claims of the remote and sparsely populated portion of Guyanese land located at the interior end of the New River Triangle, have been identified (Bebi, 2018; Ellis, 2019).

On the national security front, Guyana's territorial security has long been under threat with claims to different parts of its territory by neighbouring Suriname and Venezuela, the latter being the most bellicose and relentless. These realities have given way to a new thinking that the country needs to buttress its national security infrastructure with the introduction of a formidable "third force" a specialist paramilitary organization which could provide border protection and aid other facets of Guyana's overworked Joint Services. Guyana's Atlantic coastline on the north east is 459 Km (285 Miles long), the total length of the entire Guyanese border is 2933 Km (1822 Miles long). The current constituted army of about 3000 soldiers and an estimated 4000-4600 police personnel cannot by any means provide adequate national security, law enforcement and public safety in any sustainable way.

As a consequence, the famous May 2018 incident which took the lives of 16 Guyanese fishermen alleged to have been killed by Surinamese pirates and which was seen as reprisal attacks for the prior killing of a Surinamese drug Lord, that had hitherto posed greater threat to Guyana's national security remained a potent threat that is likely to repeat itself in the future if not properly managed (Bebi, 2018; Ellis, 2019). Essentially, the two major external threats to Guyana's territorial integrity came from two out of its three immediate neighbours, Venezuela and Suriname. Even though Brazil which has a 700 Mile boundary with Guyana has not constituted a major source of external aggression, there is no guarantee that such won't happen in the future. The vast un-policed boundary between Guyana and Brazil has a good potency for boundary disputes as both countries deepen their quest for mineral resources and economic development. In the recent years, the country's natural endowment, especially the newly found large crude oil deposits, has created new vistas for predatory neighbouring countries predispositions as exemplified by the recent external aggression from Venezuela and Suriname. The authors believe strongly that more external aggressive behaviours from the region will manifest in the face of massive new oil discoveries and enviable economic growth rate in the country.

One of the major challenges of the small states of the Caribbean including the republic of Guyana is extreme weather events and global climate change. This can be best situated within geographical and historical contexts. Centuries of colonial exploitation and the rage of the elements as a by-product of colonialism and modernisation has attenuated the impacts of climate change and its concomitant consequences in the region and Guyana in

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particular. The impacts of these will ultimately shape statecraft in profound manner. Migratory patterns in the Caribbean has also new challenges for Guyana's development The Caribbean islands are specifically vulnerable to all forms of extreme weather events and global climate change that made emigration a common practice. It impossible to understand the Caribbean without considering the impact of migration on the states of the region, and which in the first instance created some of the states of the region (International Organisation for Migration, IOM, 2017). While it is common knowledge that climate change has created severe global migration challenges the case of Guyana exacerbated with the political turmoil in Venezuela, Cuba and even Haiti. Citizens of these countries are moving to Guyana as refugees with attendant security threats. Accordingly, the (IOM, 2017) opined that with the European colonisation in the 16th century, and the subsequent massive and forced migration of African slaves to create and feed the colonial plantation economies, migration in the Caribbean including Guyana, is not a recent trend. Since the Caribbean region is situated between North and South America, it serves as a transit point for irregular migrants from South America and other places trying to reach the United States and has indescribably increased the risk of criminal behaviour across the region, some of which have posed security threats to the states of the region including the CRG. The consequential effect of this is that Guyana sits on a fault line of migratory route in a relatively troubled region of South America.

The Volume of Guyana's Oil and Economic Challenges

Following the announcement by ExxonMobil in 2015, about massive oil finds off the Coast of Guyana, the company disclosed that the Liza 1 Field, which is part of Stabroek Block marked a new economic epoch that triggered massive investments in the sector (see Figure 2). Other oil corporations joined the rush for Guyana's oil with an investment of over US$ 8 Billion by the end of 2019 (Rystad Energy, 2020). The oil finds have remained progressive and estimates put Guyana's proven oil reserve at over 8 Billion Barrels recognised within the oil sector as a good quality resources and relatively cheaper cost of production when compared to similar offshore oil ventures (Exxon Mobil, 2020).

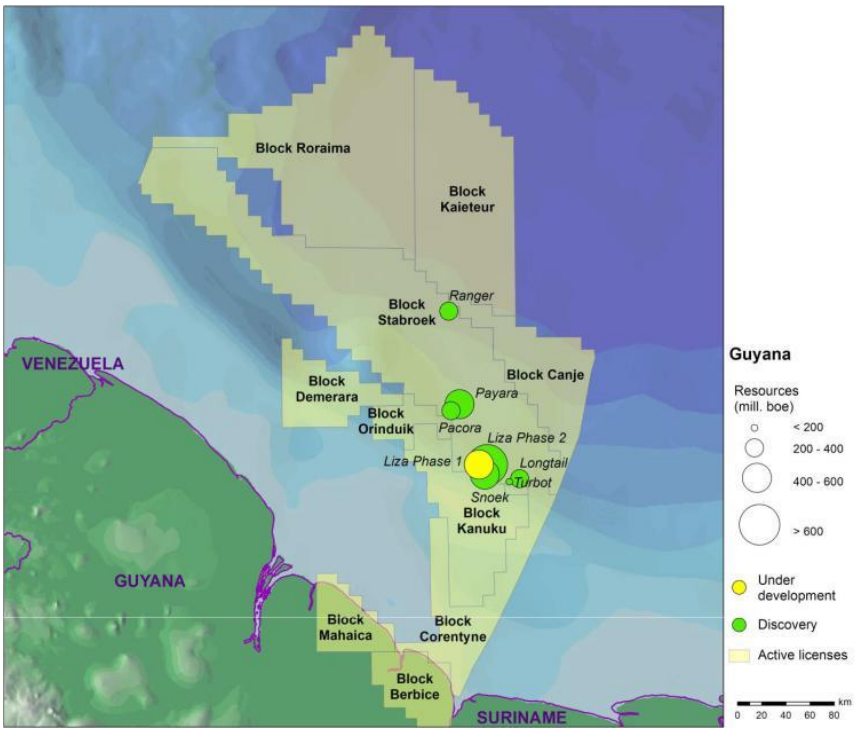

Figure 2. Oil discoveries shown within offshore lease blocks.
Source: Rystad Energy UCube

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The geographical benevolence of nature has bestowed upon Guyana unprecedented level of oil wealth and petrodollars. The year 2015 remains a watershed in the economic history of the country with the discovery of huge hydrocarbons at Liza Field off the coast of Guyana. With this discovery the country has joined the league of oil producing nations in South America and has progressively remained so with bigger oil finds in recent years. However, the new oil wealth presents new challenges with regards to oil resource utilization for development. This is against the backdrop of the curse of oil wealth in a lot of developing economies.

There are countless discourses on the correlation between huge resources and economic development. These are couched in the popular paradox of plenty and resource curse especially in petro-economies. Scholars have argued that most times petro wealth generate negative political and economic consequences within a framework of the vicissitudes of oil prices vis a vis economic planning and development (Auty, 1993; Sach and Warner, 1995: Karl, 1997). The consequences of oil price volatility on the political economy of these rich oil resource countries cannot be overemphasised. For nations with weak economic institutions, the ability to judiciously manage these oil revenues becomes quite daunting.

CRG Government Efforts in Managing its Domestic Challenges over the Years

Recognising its domestic and externally induced challenges over the years, the government of Guyana overtime has formulated policy framework to resolve the challenges. Notably, the government in its attempt to solve the problem associated with high level of poverty, climate change, and other forms of socio-cultural and political challenges such as racial consciousness or ethnic assertiveness and discord, and economic challenges, collaborated with domestic and international bodies and agencies such as CARICOM, World Bank and other multilateral agencies to take up the monumental developmental challenges confronting the country. This has remained the task of successful governments in Guyana.

Conclusions

As can be expected after a nasty and protracted election stalemate, which has become sort of commonplace in Guyana; there is a general perception held by the man in the street that ethnic and racial insecurities and tension are on the increase, though with some changes in dynamics. For example, one television commentator referenced the return of some racially pejorative terms, which were conspicuously absent from the country, ever since its embrace of socialism went into full gear in the early 1980s.

These terms he posited, were used by individuals of specific racial (contexts) rather than groups as a coded reference to other members of the Guyanese society. Since Guyana joined the ranks of major oil producers, approximately two years ago, there has been a notable shift in racial and ethnic dynamics, as ethic groups attempted to gain favourable positions in the new pecking order established by the steady flow of Caucasians, who regularly arrive to work in the oil and allied industries.

The prolonged effects of the corona virus is having a toll on Guyana like so many other developing countries, however, while Covid 19 has dislodged the economic drivers of most countries of the world after just 3 months, Guyana has been somewhat fortunate that its economy was adjudged as the fastest growing in the world (43%) in one year, due to massive income primarily from oil production. Unfortunately, this development is accompanied by its own misfortune as many Guyanese are not optimistic that they will derive much benefits from the country's new found wealth.

While the police have being solving many serious crimes with alacrity, many Guyanese remain adamant that crime and insecurity, coupled with a marked increase in the cost of living due to disruptions in supply chains internationally caused by Covid 19 remain a major source of worry. Although there are numerous large scale

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developmental projects underway, there are constant cries and accusations of ethnic exclusion due to systemic marginalization.

Recommendations

The Guyanese statecraft trajectory towards a sustainable and stable Caribbean nation in the face of precarious post-colonial history, political alliance and nuances of intra and interregional influences on a country with great economic and geo-strategic potentials and the contradictions of a small population cannot be over emphasised.

The world is presently filled with extraordinarily successful small states in virtually all the four corners of the earth. Singapore, Qatar, Oman, the UAE, Israel etc are glaring examples of states with small populations with incredible success in developmental strides. Guyana can join the league with the right policy and programmes.

The nations of the Caribbean, including the Republic of Guyana are highly studied and most of their national challenges well known by researchers and scholars who have understudied the challenges of the Southern American countries. The following recommendations therefore are proffered to ameliorate and promote national growth and development in the CRG and cement its diplomatic intercourse with its neighbouring countries.

1. First and foremost, the government of the republic should promote and encourage national integration and unification of the multiracial groups without marginalisation of any of these groups. This will significantly promote national cohesion and the unity of the state. This is against the backdrop of verifiable racial-cum ethnic divide amongst indo-Guyanese, Afro-Guyanese, Asians and indeed Latinos within the political, economic and social landscape of the country. The urgently needed cohesion is a prerequisite for stability and virile statecraft, stability and development.
2. It is imperative that the Cooperative Republic of Guyana (CRG) needs massive strengthening of the institutions of governance including the security architecture. From politics to the economy, these institutions must be reformed and upgraded to meet current sub-regional and global challenges. This is against the backdrop of the relevance of these institutions to statecraft. The whole gamut of national security and law enforcement must be reinforced to attract the best brains and guarantee enhanced efficiency. Previous studies have shown that the reward system in the security sector is abysmally disincentive and bedevilled by corruption, apathy and poor performance. Adequate trainings and manpower development of personnel in collaboration with willing states such as the US will be needed. In a nut shell, a massive security sector reform is highly recommended to protect the new found wealth in the Republic.
3. Thirdly, with great economic potentials and near-geometric growth rate, the country needs an objective over haul of demographic policies needed to attract the right kind of immigrants that can sustain the tempo of macro- economic growth and sustainable development. The suggested population growth policy is also needed to provide the needed human resources that will be needed to police the enormous land mass of CRG which is bounded by potential predatory states like Brazil and Venezuela.
4. The geo-strategic architecture of CRG needs a comprehensive over haul in the face renewed interests from the United States, Venezuela, Russia (for historical reasons) and indeed China. These Kaleidoscope of interests by global powerful nations in a small state like the CRG can jolt the nation in centripetal directions and greatly undermine its stability and development.
5. Within the CARICOM region, the Cooperative Republic of Guyana (CRG) needs to upgrade the alliance between member countries aimed at reducing competition and engender cooperation based on shared common threats and destinies. This way, the trans-Atlantic geo-strategic alliances will be more robust and effective.
6. Within the ambit of statecraft, there is the need for the country to adopt the Costa Rican example of demilitarisation to save enormous resources hitherto utilized for some nebulous national security and reallocate same for policing and public safety and social security. Inclusive leadership rooted in deep

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national patriotic culture is a prerequisite for sustainable development. This should permeate the entire country and stamped on the psyche of Guyanese via reorientation of the entire citizenry.

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SECURITY ENGINEERING PROBLEMS: DETERMINATION OF TOLERANCE INTERVALS FOR AZIMUTHAL POSITIONAL ERRORS

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Abstract. The aim of the paper is to provide an overview of the advantages and disadvantages of near-zone measurements and a comparison of near-zone and far-zone measurements. The paper is intended for specialists who will solve quite different problems - programs for numerical calculation of the far-zone field, including probe correction, back projection and gain, software for displaying the calculated values, programs for controlling the sensing equipment and measuring instruments, hardware equipment and instruments for measurements, including the design of the sensing equipment. The paper gives an overall overview as far as possible in a way that is understandable to experts in different fields, as it is necessary for them to be able to interact with each other and use a common language. The paper gives an analysis of the tolerance requirements for the X-Y positioning mechanism (planar sensing). For any measurement technique, one of the basic requirements is a reliable estimation of the measurement errors, and this is especially true for methods that use a high level of mathematical analysis, such as near-zone antenna measurements. Determining error margins for any measurement system for a given antenna/probe/near-zone combination can be a difficult and time-consuming task, and mathematical complexity is a major reason for the difficulty.

Keywords: probe correction; main and lateral lobe; azimuthal characteristics; final sensing; error functions; laser interferometer; correlation function

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1. Introduction

There is a separate strand of literature devoted to engineering security problems (e.g. (Ivanka, Chuda, 2015; Buday, Grinchuk, Gromyko, 2017, Prabhakaran, Selvadurai, 2018; Bayuk, 2021; Chou et al., 2021).

To determine the tolerance requirements with respect to the accuracy of the measurement mechanism in the antenna/probe/near-zone combination is a time-consuming task and the mathematical complexity is the main reason for the difficulty.

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Therefore, attempts are often made to circumvent mathematical methods and try to set error limits for a general measurement technique by measuring for a particular antenna. In this approach, the results of the far-zone and near-zone measurements are compared, and the differences between the two methods are taken as a measure of the error in the near-zone measurements. The limitations of this approach are as follows:

a) The observed differences are partly and perhaps mainly due to errors in the remote zone,

b) it is difficult to generalise one result to another antenna or measurement system,

c) the most critical measurement parameters or contributions from individual error sources cannot be determined,

d) remote zone measurements may be impractical for certain types of antennas that are suitable for measurement in the near zone.

This is not to say that such comparisons have no value. They demonstrate reliability, help to ensure credibility without detailed mathematical analysis, and show possible areas where more detailed analysis is needed. They are one part of the error analysis, but they certainly do not form the whole picture. A complete and general analysis requires a combination of different approaches, both analytical and experimental, to identify all possible sources of error and estimate their contributions to the final calculated results. Such an analysis provides a means for the systems engineer to determine the requirements for each part of the measurement system in the near zone and for measurement theory experts to estimatethe uncertainty in the measured quantities.

The prerequisite of the analysis is to determine all significant sources of error, measure or estimate all sources of measurement error in the near zone, and in many cases determine the shape of the functional dependence of the errors. The error equations between the measurement errors in the near zone and the results of the calculations for the far zone were derived. The combinations of the individual error components are identified to obtain a realistic estimate of the resulting measurement errors. Detailed theoretical relationships that are important for measurement refinement (finite-dimensional analysis of the sensing for cylindrical sensing and analysis of the accuracy of the sensing mechanism) are presented.

These relations form the basis for the analysis of the tolerance requirements for the positioning mechanism for cylindrical measurements with respect to the positioning mechanism accuracies (azimuth/elevation). The cylindrical sensing technique has probably attracted the least interest in error analysis of all the commonly used sensing techniques. It was generally assumed that the errors would be similar to those for planar surface measurements, which is of course true, but some sources of error that have different implications need to be investigated. Detailed analyses have shown that the main source of errors is due to the influence of the measurement system.

2. Basic Errors in the Measured Antenna Settings

For the following analysis, we consider the spherical (R, θ, φ) and cylindrical (r, φ, z) coordinate systems.

Typically, the axis of rotation (z-axis) will be vertical for scanning on a cylindrical surface. Errors in the alignment of the antenna being measured will cause the antenna coordinate system as defined by the mirror, base markers, or telescope to not be exactly aligned relative to the coordinate system of the scanning mechanism. Since the resulting characteristic is defined relative to the mechanical sensing plane, misalignment of the measured

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antenna will cause a maximum radiation error equal to the azimuthal and elevation rotation errors. A small misalignment will cause approximately equivalent azimuth and elevation errors that are not too far off axis.

The theoretical analysis for planar sensing in the x,y plane, as presented in (Rensburg et al., 2020; Just, 1981; Chejbal, Kovarik, 1981; Epjar et al., 1988; Newell, 1988; Newell, Lee, 2000; OHDE, 2007/2008) can be used to estimate the errors in the probe position in the z-axis direction. For the case where the main beam is approximately perpendicular to the z-axis, the errors for the gain maximum and side lobes are

$$\Delta G(\theta,\varphi)_{dB} \le \frac{8{,}7\Delta_z(\text{rms})}{\eta D_z} g(\theta,\varphi) \quad \text{for the main lobe,} \qquad (1)$$

$$\Delta P(\theta,\varphi)_{dB} \le \frac{4{,}3\Delta_z(\theta,\varphi)}{D_z} g(\theta,\varphi) \quad \text{for the lateral lobes,} \qquad (2)$$

Where:
G is the gain of the antenna,
P is the relative diagram, Dz is the principal dimension of the antenna,
η is the efficiency of the antenna aperture, and Δz is the position error in the z-axis.

The function $g(\theta,\varphi)$ is the ratio of the maximum of the diagram to the amplitude in the direction under consideration. For example, for a side lobe of -40 dB, $g(\theta,\varphi)$ is equal to 100. In equations (1) and (2), we consider the error spectrum for the angles (θ,φ). For the random error case, errors with the same rms value (standard deviation) are considered, which is emphasized by the rms notation. Considering the analysis, it is clear that all conclusions, which are related to in-plane sensing (x, y position error), including the examples given, apply analogously. If we know the error spectrum Δz-position, we obtain very realistic estimates of the near-zone errors. Upper bounds on the errors when we consider only the maximum value of the errors arise in rather special cases.

3. Radial and Azimuthal Positional Errors

The effect of the radius errors is similar to the z-direction position errors for planar sensing because these errors predominantly produce phase errors as a function of z and azimuth φ. For a fan-shaped measured antenna beam (narrow beam in the elevation plane and wide beam in the azimuthal plane) where the near-field phase is nearly constant on the cylindrical surface, the equations for the radius errors are identical to those for the z-direction position errors for planar sensing. For a pencil beam (a narrow beam for both azimuthal and levation planes), the magnitude of the phase for a given radius error varies with azimuth angle. This results in an approximate average phase error being considered in this case, cylindrical scanning. Therefore, as a result, we use the equations for planar scanning for a beam deflected 45° from the z-axis.

The mathematical relations for the main beam and side lobes of the pencil beam for the wavelength are λ:

$$\Delta G(\theta,\varphi)_{dB} \le \frac{22}{\sqrt{\eta}}\left(\frac{\delta_r(\text{rms})}{\lambda}\right)^2 g(\theta,\varphi) \quad \text{for the pencil main volume,} \qquad (3)$$

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$$\Delta P(\theta,\varphi)_{dB} \le \frac{10\delta_r(\theta,\varphi)}{\lambda} g(\theta,\varphi) \quad \text{for the side lobes of the pencil bundle.} \qquad (4)$$

In relations (3) and (4) we consider the error spectrum $\delta_r(\theta,\varphi)$. For the random error case, errors with the same rms value (standard deviation) are considered, which is emphasized by the notation rms. If we know the error spectrum $\delta_r(\theta,\varphi)$ of the z position, we obtain very realistic estimates of the errors in the near zone. Upper bounds on the errors, where we consider only the maximum value of the errors, arise in rather special cases.

The effect of azimuthal position errors can also be determined using a modified version of the equations for z-axis errors in planar sensing. The modification uses the y position errors that cause the azimuthal position errors. The y position when the probe moves azimuthally along the cylinder, where the differential of this position will give the corresponding error:

$$y = r\,[\cos(\varphi - 1)], \qquad \delta_y(\varphi) = r \sin(\varphi)\,\delta_\varphi. \qquad (5)$$

The y errors that have the greatest effect are the errors within the near-field collimation region. This region is practically equal to the aperture region of the measured antenna. For an antenna with an aperture width Dx in the x-direction, the collimation region on the cylindrical scanning surface is bounded approximately by the angles

$$\varphi_y = \pm \arcsin[D_x/(2r)]. \qquad (6)$$

Therefore, the error y will vary between zero when $\varphi = 0$ and the maximum

$$\delta_y(\varphi) = \pi D_x \delta_\varphi/360 \qquad (7)$$

for δ_φ in degrees. The average error y is equal to one half of the value in equation (7). To determine the effect of azimuthal positional errors we use equations (3) and (4) with this error:

$$\Delta G(\theta,\varphi)_{dB} \le \frac{22}{\sqrt{\eta}} \left(\frac{\pi D_x \delta_\varphi(\text{rms})}{180\lambda} \right)^2 g(\theta,\varphi) \qquad (8)$$

$$\Delta P(\theta,\varphi)_{dB} \le \frac{\pi D_x \delta_\varphi(\theta,\varphi)}{18\lambda} g(\theta,\varphi) \qquad (9)$$

Typical positional errors that can occur in cylindrical measurements are errors created by misalignment of the sensing mechanism on the straight line and the rotation axis of the antenna being measured. These errors can be estimated using relations (3) to (9). In addition to the radius errors, the actual alignment of the probe inside the measurement system in the near zone on the cylindrical surface is very important.Ideally, the x1 axis must be perpendicular to the z0 rotation axis and also intersect this axis.

Furthermore, the probe axis z1 must be parallel to the axis z0. It is well known from the theory of nearzone measurement on a plane that poor probe alignment translates directly to errors in the far zone, where the error is proportional to the change in probe characteristic. In the case of cylindrical sensing, this problem is somewhat more complicated and is presented in the area of measurement error analysis.

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In near-zone planar sensing, the antenna to be measured is mounted stationary and the near-zone probe moves along the planar surface in both the x and y directions so that the array of field patterns (amplitude and phase) can be sensed. Similarly, when scanning on a cylindrical surface, we scan the matrix of field samples for motion in the z-direction and in the azimuth φ. The scanning range for measurement in the z-direction is important when the accuracy of measurement on a cylindrical surface in the near zone is considered. The size of the antenna to be measured and the size and location of the final sensing area (cylinder) define the critical angle Φ. The calculated antenna radiation characteristics will be valid in the region between ±Φ. For a given sensing range L, the following applies:

$$L = D + P + 2d \text{ tg } \Phi, \tag{10}$$

Where:
D is the diameter of the measured antenna, P is the diameter of the probe and d is the distance between the probe and the measured antenna. Full angular coverage can only be achieved by sensing on the full spherical surface in the near zone. For example, a critical angle Φ= 70° is achieved with a scan that is six wavelengths on each side larger than the aperture of the antenna, two wavelengths away from the antenna.

The limited sensing area has two effects. First, for an area larger than the antenna aperture, the resulting radiation areas are only valid within the area. This criterion is used to determine the minimum scan plane dimension for a given desired angular area and separation distance d. Since the lower limit for d is determined by the physical structure of the antenna and multiple reflections, a trade-off is usually required between both maximum angular coverage along with error reduction due to limited scanning (when small d is required) and minimum multiple reflections (when large d is required).

Another effect of the limited sensing area is the occurrence of calculation errors even for the "valid area". For planar sensing, this error can be estimated from knowledge of the measured data at the edge of the sensing area, even though the error arises from neglecting all data on an infinite plane outside the sensing area. For a preliminary estimation of the error due to the limited sensing area for measurements on a planar area, the following applies:

$$\frac{|\Delta I(\mathbf{K})|}{|I(\mathbf{K})|} \leq \frac{\alpha \lambda L_m b_m(\rho', \varphi_\rho)}{2S \cos\gamma_m} \frac{|I(\mathbf{K}_0)|}{|I(\mathbf{K})|} \tag{11}$$

Where:
S is the area of the antenna aperture, Lm is the maximum width of the sensing area,
$\alpha \approx 1 - 5$ is the amplitude drop coefficient (1 for uniform irradiance, but practically no more than 4 for commonly used irradiance), $b_m(\rho', \varphi_\rho)$ is the maximum amplitude of the probe output at the edge of the sensing area relative to the maximum probe output at the sensing area, and $|I(\mathbf{K}_0)/I(\mathbf{K})|$ is the ratio of the maximum amplitude in the $\mathbf{K}_0$ direction to the amplitude in the K direction (i.e. The inverted value of the normalised diagram in the far zone). As an upper bound, (11) holds for angles up to 90°, but very roughly, equation (11) can be said to represent a fairly reasonable estimate of the upper error for a range of angles less than Φ/2, and for larger angles the estimate of (11) is much higher than the actual errors.

That relationship requires less information, but generally gives a much larger upper bound on the error. This relationship can be applied even for antennas that are separable in the x,y plane only when scanning along the antenna axes, as has been shown not only theoretically but also experimentally. However, it should be noted that the above relation does not consider the phase change along the perimeter of the sensing area when measuring

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along the antenna axes and therefore could give larger errors in most cases. Therefore, it can be assumed that this relation for planar sensing can be used as an upper estimate for cylindrical sensing as well.

3. Experimental results of error analysis

In the next part of the paper we present examples of measurements, comparison of measurements on the cylindrical surface and in the far zone, numerical simulation of errors that occur during measurements and statistical processing of 10 measurements for cylindrical measurements (one slice) for a probe consisting of both a shortened dipole and an open reduced rectangular waveguide. A comparison of the statistical processing of the measurements and estimates of the effect of random errors is shown, considering a suitable error correlation interval. The maximum values of the standard deviations of the σ ten measurements for wavelength λ = 32 mm were approximately 0.02 (0.2 dB for gain). However, it is important to note that this figure refers to the total errors due to both the effect of the sensing mechanism (which were quite significant due to inaccurate manual positioning and a not very rigid sensing mechanism), as well as the errors of all instruments used (amplitude errors due to receiver non-linearity and source amplitude instability with maximum standard deviations σ_φ estimated at 0.01 and phase errors due to phase changes in the microwave path including rotary couplers). The resulting standard deviations of σ_φ all phase errors were estimated to be 0.02 (in the middle of the sensing interval) to 0.1 (at the edges of the sensing interval). Error estimation was performed using backward FFT from the measured error spectra (which was obtained using FFT from the measured values). Numerical simulations were performed for different error variations. In particular, the influence of the type of correlation function, the correlation interval used and the shape of the measured amplitude and phase were studied. The use of numerical simulations allowed investigating much more complex shapes of amplitudes and phases as well as various types of correlation functions and random processes. This of course on the one hand leads to much more realistic estimates that are in better agreement with experimental data, but on the other hand this approach is more limited to special types of errors and therefore does not give an idea of the potential for much larger errors in some special cases (the analysis is instead focused on somewhat exceptional cases where special error distributions produce the largest possible errors). For testing, errors were created by incorrect alignment of the sensing mechanism on the straight line and the rotation axis of the measured antenna. The base of the tower was tilted to form a known angular tilt between the z-axis of rotation and the scan axis. This is a typical positional error that can occur in cylindrical measurements. The tower was rotated by 0.1° and measurements made. Comparison of the characteristics in the far zone without and with the above error gives directly the magnitude of the effect for this special type of error. The tilt of the tower causes a maximum radius error of 1.12 mm and a standard deviation of 0.76 mm. Equation (3) gives an error estimate of 0.05 dB and the change in measured gain was 0.052 dB.

Therefore, for the investigation, a known error was inserted into the radius size to obtain the sensitivity of the radiation pattern in the far zone. The measured antenna was mounted on a rotating device that was mounted on an automatic sliding device that allowed the radius to be changed. The measured X-band antenna with sum and difference beam was first measured using planar scanning to obtain a reference radiation pattern. Then cylindrical scanning was used with a scanning range of 100° (0.5° rotation step) and a vertical probe movement of 2 m (16.5 mm step). The radius size (distance of the probe from the axis of rotation of the measured antenna) was set to 1.1 m. To test the device for measurements on a cylindrical surface, the radius deflection was set to 0, -0,2 λ, -0,4 λ , .. -1,6 λ. These data were processed so that the radius size was considered to be the same (1.1 m) for all cases, which caused a processing error because the radius actually varied. The results are shown in Figures 1,2,3,4.

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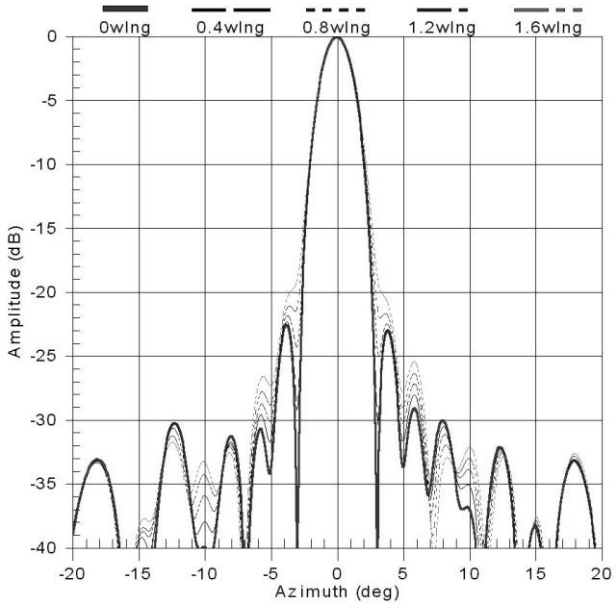

Figure 1. Radius change of 0, -0,4 λ, -0,8 λ , -1,2 λ and -1,6 λ for the sum beam in azimuth

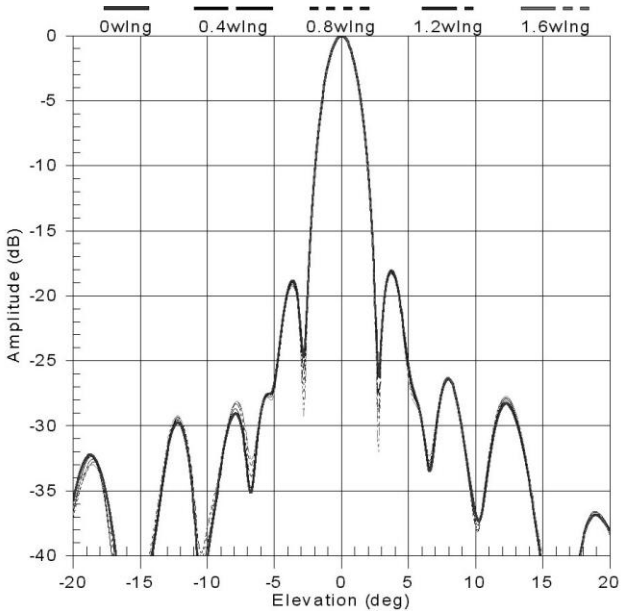

Figure 2. Radius change of 0, -0.4λ, -0.8λ, -1.2λ and -1.6λ for the summed beam in elevation

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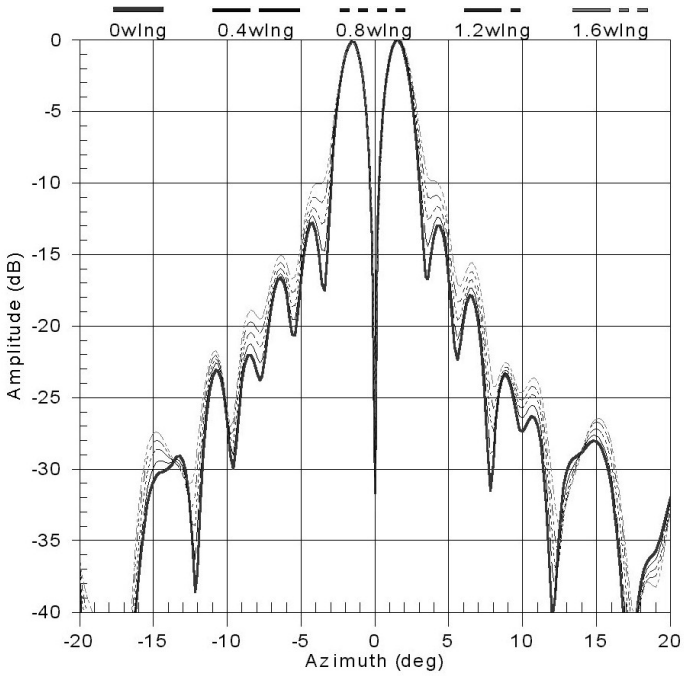

Figure 3. Radius change of 0, -0.4λ , -0.8λ, -1.2λ and -1.6λ for the difference beam in elevation

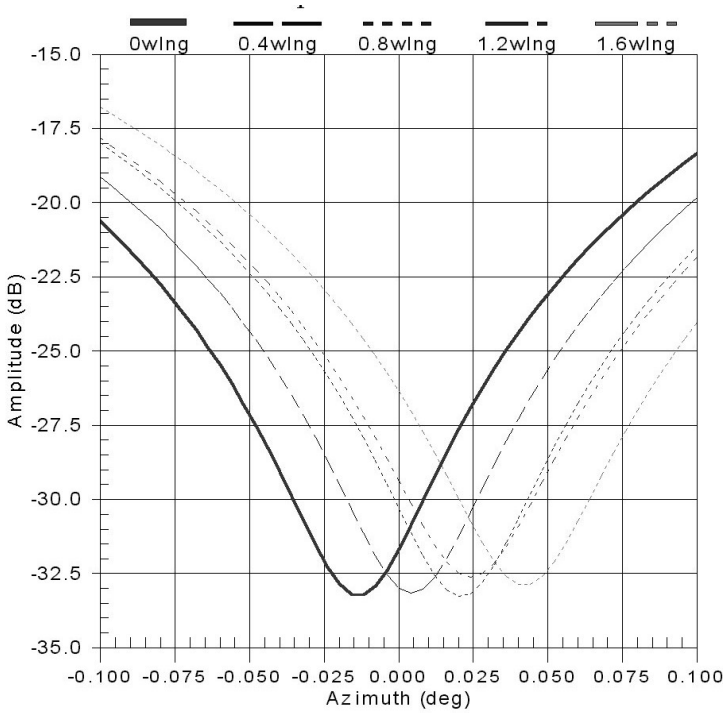

Figure 4. Radius change by 0, -0.4λ, -0.8λ, -1.2λ and -1.6λ for the summation beam in elevation (detailed waveform near zero)

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The azimuthal characteristics varied slightly, as demonstrated by the comparison of individual characteristics in Figure 1. A change in radius of -0.4λ corresponds to the 0.4wlng designation, and similarly for the other values in Figs. 1 to 4. The elevation beam characteristics were found to be relatively insensitive (hardly changed), as demonstrated by the comparison of the individual characteristics in Fig.2. Comparison of the difference beam revealed similar behavior for the azimuthal and elevation characteristics. However, for the azimuthal characteristic, a more significant change in zero position was found for the difference beam (0.05°), as demonstrated by the comparison of the individual characteristics in Figures 3 and 4. It can be summarized that the effect of the change in radius is almost negligible for the elevation beam characteristic and is more significant for the azimuthal characteristic. The measured data showed a preliminary conclusion that the target accuracy for radius determination must be better than 0.1λ. This is less stringent than usually considered. However, due to the change in the position of the zero of the difference beam in the azimuthal characteristic, further investigation would be advisable.

In the next experiment, data were measured along the antenna axes at a distance of 25 cm from a circular array with a diameter of 80 cm. The sensing range was 213 cm and this range was gradually reduced. The wavelength used was 3.26 cm. A similar experiment was performed for a reflector antenna with a frequency of 60 GHz. Comparisons showed that the conclusions presented for the limited sensing area analysis were valid. Of course, these experiments were performed for "planar sensing" (along the antenna axes). Since these experiments were performed only for the axes, it can be assumed that even smaller errors will arise when scanning on a cylindrical surface (this will be an "average" value over all scans). Since these errors will usually be very small, it is probably not necessary to find better estimates of the errors.

In Table 1, the errors calculated from relation (11) are given for some parameters of the calculated radiation characteristics in the far zone of a typical antenna operating in the X-band with sum and difference beam. Wavelength = λ0.0326 m¸ aperture area S = 0.5 m2, maximum scanning area width Lm =1.6 m, λ= 3, maximum angle λ= 60°, amplitude drop at the edge of the scanning area -45 dB. The sidelobe level was -25 dB, the "zero" level of the differential beam was -30 dB.

Table 1. Calculated errors

	Radiation characteristic parameter	Errors due to final scanning
Sum bundle	Maximum axis gain	**±0,01 dB**
	Level of the lateral lobes	**±0,16 dB**
	Bundle width ϕ_0	**±0,002 ϕ_0**
	Polarization ratio on axis	**±0,001**
Differential bundle	The value of "zero"	**±0,28 dB**
	Shift "zero"	Negligible
	Main volumes	**±0,01 dB**

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Conclusions

Thus, it can be summarized that for accurate measurements in the near zone, the sensing device should have a probe positioning accuracy of the order of one hundredth of a wavelength for the highest frequency considered. Except for very special error waveforms, a standard deviation value of approximately λ/100 is usually sufficient (errors greater than three times the standard deviation will occur with a probability of approximately one per mil).

Since antennas with smaller aperture sizes can be expected to be used for the highest frequencies, it is possible to design a smaller sensing device with higher accuracy or to ensure that the central part of the sensing device has higher accuracy. Another possibility is to accurately measure the errors of a stable sensing device and correct the errors in the z-direction using special software, or to better adjust the sensing device or refine the error estimates and confirm that the device can be used. Similarly, it is possible to estimate the magnitude of δ_{φ}. Since the average error δ_y (φ) is equal to one half of the value in equation (7), δ_y (φ) = π D_x δ_{φ} /180 and therefore $\delta_{\varphi}=0{,}57\lambda/D_x$. If we consider that usually the dimension

Dx will be less than 30 λ, then it δ_{φ} should be about 0.02° (which, except in special cases, may not be the maximum error but rather the standard deviation). Note that different manufacturers specify roughly the same values.

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