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RELATION BETWEEN FINANCIAL LITERACY AND CARBON FOOTPRINT: REVIEW ON IMPLICATIONS FOR SUSTAINABLE DEVELOPMENT

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Introduction. Financial literacy has been recognized worldwide as a significant element of stability and economic and financial growth. With the evolution of financial instruments, the growing importance of financial inclusion, its correlation with financial literacy, and the effects they have on sustainability, the concept of financial literacy is dramatically changing and getting more inclusive, spreading the focus on sustainability, sustainable consumption, and environmental preservation.

Aim and tasks. The aim of the study is to examine the connection between the population's financial literacy level and greenhouse gas emissions. The working hypothesis claims that there is a relationship between financial literacy and the carbon footprint.

Results. The correlation and regression analyses were the main tools in the study, while the dataset for 2014 covered 137 countries, with the main dependent variables being carbon emissions per capita, per unit of gross domestic product, and per unit of energy. The partial correlation coefficients between financial literacy rating and carbon footprint variables were insignificant when controlled for economic development, represented by per capita gross domestic product. Estimated econometric models with financial literacy in quadratic form were adequate and showed a significant connection between financial literacy and carbon emissions per capita and per gross domestic product at the 5% level. The relationship with carbon emissions per unit of energy was significant at the 10% level. In all three models, the relationships followed an inverse U-shape, with low financial literacy increasing the carbon footprint and higher financial literacy decreasing it. The turning numbers for financial literacy were 35.8% for carbon emissions per capita, 41.4% for emissions per unit of gross domestic product, and 32.4% for emissions per unit of energy.

Conclusions. Financial literacy was indeed associated with carbon emissions in a complex, non-linear way. The effect of energy consumption on carbon emissions was stronger than financial literacy and appeared to be the driving force for the increase in carbon emissions. With low financial literacy observed in underdeveloped countries, the situation was not favorable for the environment. As financial literacy increased, welfare, income, and consumption increased too, leading to an increase in greenhouse gas emissions, i.e., a bigger CO_2 footprint. Once a certain stage of economic development was reached, the relationship was reversed, i.e., in developed countries, financial literacy worked towards reducing the carbon footprint and protecting the environment.

Keywords: sustainability, carbon footprint, financial literacy, partial correlation, regression model.

1. Introduction.

Financial literacy appears to be of greater significance than ever given the economic and social circumstances of today (Şimandan et al., 2022; Kurmanov et al., 2019; Abuseridze et al., 2022). Improvement of the human capital brought about by raising people's educational levels increases worker productivity, which raises the economy's output. As a result, improvements in the educational sector have been shown to positively affect the country's economic growth (Paşa et al., 2022). Comprehending the scientific research on financial education, saving, and consumer behavior is crucial given the significance of the challenges for governments in improving the balance of environmental, economic, and social sustainability (López-Medina et al., 2022).

According to the OECD (2013), a connection between individual financial decisions, society, and environment could constitute a vital element of the definition of financial education. Lusardi and Mitchell (2008) argue that the goal of financial education programs should go beyond addressing the individual financial well-being of participants and include addressing societal issues like environmental risks, sustainability, and gender equality given the differences in financial literacy and decision-making ability between men and women. Although integration of these elements in financial education programs is still in its early stages, the Federal Office for the Environment (2020) emphasizes how important they are for handling the rising environmental risk.

A more sustainable economy and society are the results of financial education, which encourages more responsible and ecologically friendly product consumption (Muñoz-Céspedes et al., 2021). Hira (2012) recommends including sustainability issues in financial education programs to foster long-term family and community stability while promoting responsible resource management.

Due to the significance of financial education in making sustainable financial and economic decisions that will enhance future well-being, both academics and economics policymakers are becoming increasingly intrigued by it (Hira, 2012; Karakoç & Yeşildağ, 2017).

As a foundation for achieving personal financial wealth, financial literacy should be incorporated into future public policies for financial education both inside and outside of the classroom (Seitzhanov et al., 2020; Paşa et al., 2022). This will have a positive effect on national economic growth and sustainable economic development. Political support for financial education is based on the tacit premise that there is a positive relationship between effort and result. As more (formal) financial education activities are implemented, the consumers' level of financial education will rise, supporting more appropriate and responsible financial decisions (Şimandan et al., 2022).

Policy and theory disagree in their assessments about the outcomes of financial education initiatives (Mitchell & Lusardi, 2015). The literature ranges from writers who see financial education as a way to encourage behaviors that lead to increased sustainability (Hira, 2012) or gender equality (Driva et al., 2016; Hung et al., 2012) to reports released by international public organizations that uncritically recommend expanding financial education programs, such as OECD reports (2012).. A more sustainable society and economy also implies more sustainable consumption behavior, and thus, financial literacy has a direct effect on more sustainable financial product use. Financial literacy is important to ensure the sustainable development of individuals and society (Swiecka et al., 2020). The higher financial literacy, especially of the young population, the more favorable the level of economic indicators, which multiplies in the economy and fosters sustainable development (Karakoç & Yeşildağ, 2017).

Sustainable development and financial inclusion are both on the development policymakers' agenda and the focus of the researchers (Ozili, 2022). Many countries now place a high priority on financial inclusion when developing their social and economic policies (Cull et al., 2021; Dabla-Norris et al., 2021). Ensuring people and businesses have access to basic and affordable financial services in the formal financial sector is among the primary objectives of financial inclusion (Liu et al., 2021; Ozili, 2021a, 2021b). In the current economic environment, financial inclusion is crucial for a nation's wide, inclusive, and sustainable growth.

The economic and social advantages that financial inclusion provides to people, businesses, and governments in pursuit of sustainability can be considered a metaphor for the relationship between financial inclusion and sustainable development. (Ozili, 2022). Each country's financial system is required to function well to provide a variety of financial and banking services, including credit facilities, savings plans, insurance products, and financial inclusion initiatives, to the country's vulnerable groups in general and its citizens (Cnaan et al., 2012; Demirguc-Kunt & Klapper, 2013).

Governments' pursuit of financial inclusion is dependent on extensive research that demonstrates how it fosters economic growth (Kim, et al., 2018; Todorov, et al., 2023), greater financial stability (Neaime & Gaysset, 2018), poverty reduction (Koomson et al., 2020), reduction in income inequality (Huang & Zhang, 2020), financial literacy (Grohmann et al., 2018). According to a recent study on EU member states, financial inclusion has a greater influence on economic output in low-income and recent member countries than in high-income and earlier EU member countries. (Matekenya et al., 2021). This confirms the importance of the correlation between financial inclusion, financial literacy and sustainability, and the need for more and deeper research on the topic.

However, little research has been conducted regarding the relationship between financial inclusion and sustainable development. Addressing current issues that call for the intersection of financial inclusion and sustainable development will require more research. The increasing global interest in financial inclusion and sustainable development demonstrates the importance of these topics to understand, not only for their potential to reduce poverty and protect resources but also for their socio-economic and eco-economic advantages. Researchers who investigate development issues should raise the scientific debate and insist on the development of a research agenda that considers the combined role of financial inclusion and sustainable development in making the world a better place.

2. Literature review.

Financial literacy can explain a considerable proportion of wealth inequality (French & McKillop, 2016). In this aspect, it is related to financial inclusion since high financial literacy implies a prominent level of financial inclusion in the population. On the other hand, high financial literacy is associated with sustainable consumption, personal finance management and improved well-being. Financial literacy has been recognized worldwide as a significant element of stability and economic and financial growth (Potrich et al., 2015). It is one of the factors that ensures sustainable development in society (Krechovská, 2015). Bryant (2013) claims that economic growth and sustainability are rooted in the financial literacy of individuals.

The Organization for Economic Cooperation and Development (OECD), defines financial literacy as “the knowledge of financial products, skills, attitudes, and behaviors needed to make rational decisions and achieve individual financial well-being” (OECD, 2018). The European Commission defines financial literacy as "the knowledge and skills needed to make important financial decisions" (European Commission, 2022). Financial literacy is a multi-layered issue of significant importance for the economy, society, and sustainable development (Swiecka et al., 2020). Financial literacy is an extremely broad concept that cannot be explicitly defined by the authors due to its interdisciplinary nature and the many social and economic aspects it affects. According to Hastings et al. (2012, p. 5), financial literacy is “the ability to use knowledge and skills to manage one's financial resources effectively for lifetime financial security.” To substantially improve a person's financial literacy through the acquisition of new knowledge and abilities, financial literacy education focuses on developing personal financial skills and capacities (Sterling et al., 2017).

The definition of sustainability was introduced in 1987 by the United Nations Brundtland Commission in the “Our Common Future Report”. Sustainability was defined as “meeting the needs of the present without compromising the ability of future generations to meet their own needs” (Brundtland, 1987).

Two decades later, the United Nations Sustainable Development Goals (17 themes) have become the strongest directive for sustainability education policy and practice (Sterling et al., 2017). Many studies note the unique role of financial inclusion in achieving most of the goals of sustainable development, which is one of the main guidelines of this millennium (Kuzior et al., 2022).

Financial literacy and environmental knowledge (i.e., eco-literacy) are considered factors that increase preferences for ethical financial companies, which in turn play a key role in promoting sustainable investments (Getzner & Grabner-Kraüter, 2004). In the last few years, new financial instruments with sustainable or green features have been introduced all over the financial market. Consequently, financial literacy is getting more complex, and sustainability literacy is becoming more important. Nowadays, financial literacy comprises not only the skills, values, and behaviors that contribute to financial well-being but also the advantages that it brings to the advancement of society and the environment (Gedvilaitė et al., 2022).

A recent study by Gutche et al. (2021) shows that financially literate individuals who are more aware of sustainable investments and understand the lower participation costs tend to avoid sustainable financial products. They explain this by avoiding limited risk diversification and restricted investment opportunities (Iliev et al., 2023) related to sustainable investment strategies (e.g., negative screening), which shows the lack of information regarding sustainable investment instruments, i.e., the need for deepening the relationship between sustainable finances and financial literacy.

With the evolution of financial instruments, the growing importance of financial inclusion, its correlation with financial literacy and the effects they have on sustainability, the concept of financial literacy is dramatically changing. Sustainability literacy is defined as "the knowledge, skills and mindsets that allow individuals to become deeply committed to building a sustainable future and assisting in making informed and effective decisions to this end" (Glavic & Lukman, 2007). The definition of "financial literacy" has grown to include not only mathematical skills and appropriate financial knowledge but also the beneficial effects on social and environmental development. The term "sustainable financial literacy" can refer to an updated definition of financial literacy that also considers sustainability (OECD, 2018). The practitioners have suggested the definition of "sustainable finance literacy," meaning an understanding of sustainable financial products and their use for promoting sustainable development goals, which plays a key role in the integration of ESG factors into financial decisions (Dumitrescu, 2022). Filippini et al. (2021) defined sustainable financial literacy as the comprehension by retail investors of the rules, expectations, and benchmarks for financial instruments with sustainable features.

The empirical studies about the connection between financial literacy and carbon footprints were not found in the major indexing and referencing databases (including Scopus and Web of Science). Even if such studies were performed, they did not get enough attention in the scientific community. Nevertheless, there are some papers that came close to the problem when analyzing the link between the carbon footprint and education (Ding et al., 2018; Mooney et al., 2022; Shiao et al., 2013; Uchehara et al., 2022), or between the carbon footprint and citizens' awareness of their general and individual contribution to greenhouse gas emissions (Dosa & Russ, 2018; Kolenaty et al., 2022; Scharl et al., 2015; Scharl et al., 2016; Schrills et al., 2021;). When analyzing the main factors affecting the quality of the environment Fakher (2019) studied the connection between carbon footprint and financial development level, while Heinonen et al. (2022) found that the indicator measuring the intensity of greenhouse gas emissions to the monetary expenses of the households revealed valuable information about policy targeting demand-side solutions that aim to improve the climate-literacy of consumers and impact their future spending behavior.

Fakher (2019) used Bayesian analysis, averaging, and weighted least squares on data for 22 indicators for developing countries. The study period covered the time from 1996 to 2016. The results showed that energy consumption, population density, natural population growth and added value of industry

had the greatest importance for the ecological footprint. The influence of urbanization, literacy and foreign direct investment was weaker. The results regarding financial freedom, trade freedom, the "capital-labor" relationship and financial development in general were contradictory. Shiao et al. (2013) applied "structural equation modeling" to derive guidelines for improving the green literacy of construction contractors through the improvement of training courses. The Delphi method and modeling results showed that course content should include not only knowledge of the facts regarding greenhouse gas emissions, but also knowledge of actions, their consequences, and their relationship to environmentally responsible behavior.

Zhang et al. (2021) used a large macro-panel with data on 101 countries for the period 2006–2016. Based on correlation (and partial correlation) analysis, they estimated the relationship between subjective well-being and indicators of environmental quality. They found that for developed countries, the environmental carbon footprint had a significant negative impact on subjective well-being. Ding et al. (2018) used geographically weighted regression analysis with panel data on the carbon footprint of energy consumption for the provinces of China over the period 2010–2014. Their results showed that, overall, the development of science popularization resources has a positive effect on reducing energy consumption and lowering the carbon footprint. Uchehara et al. (2022) developed a rating system for evaluating infrastructure projects in terms of sustainable development. At the same time, 36 indicators are used, through which a general assessment of the effect on the climate was made.

Schrills et al. (2021) designed a digital assistant to help users with information about the footprint of individual products, services, and to offer alternatives. To establish the basic requirements of users for such an application, they conducted an online survey in which 249 respondents took part. Heinonen et al. (2022) examined the relationship between consumption and carbon footprint. The data was collected through a survey of 8,000 respondents in the Nordic countries. The main indicator used in the analysis was "average carbon intensity per unit of monetary spending".

The results showed that additional efforts are needed to enhance the climate-literacy of consumers, which would allow them to make informed decisions when consuming goods and services. Kolenaty et al. (2022) analyzed the relationship between different 'CO_2 League' programs meant to stimulate climate-responsible behavior in educational institutions. Information is gathered about the content of the courses, educational practices, and through focus group interviews that covered 123 respondents in 47 schools. The results showed that, in addition to the concept of the carbon footprint, the process of measuring each person's individual contribution is also important for engaging in personal climate actions.

Dosa and Russ (2020) conducted an interview with students and found that even when students were willing to help protect the environment and reduce greenhouse gas emissions, having "carbon literacy" or "quantitative literacy" was not enough. Skills were needed to assess the danger of a high carbon footprint and to make adequate decisions to reduce the harmful impact on nature.

Based on the importance of financial literacy and its connections with the sustainable development and nature preservation behavior on one side and in the light of the lack of empirical studies that link financial literacy to the carbon foot print on the other, this *paper's goal* was defined as to examine the impact of the population's financial literacy level on greenhouse gas emissions (carbon footprint).

The *hypothesis* claims that there is a relationship between financial literacy and the carbon footprint of population.

3. Methodology.

As much as conducting empirical analysis of the carbon footprint with relation to educational and financial issues, the involved methods varied from qualitative (like online surveys and face-to-face interviews) to sophisticated econometric techniques that included Bayesian analysis and structural equation modeling, dynamic models, innovation modelling, regression analysis, and correlation coefficients (Ramazanov & Petrova, 2020; (Odinokova & Akhmedyarov, 2022).

In accordance with the study's aim, correlation analysis was selected as an appropriate tool when assessing the strength of the connection between financial literacy and carbon footprint. Correlation coefficients were computed as Pearson's product moment coefficients by the following formula:

$$r_{xy} = \frac{\sum_{i=1}^{n}(x_i-\bar{x})(y_i-\bar{y})}{\sqrt{\sum_{i=1}^{n}(x_i-\bar{x})^2 \times \sum_{i=1}^{n}(y_i-\bar{y})^2}} \quad (1)$$

where: y_i is the dependent variable representing the carbon footprint across the cross-section data;

x_i – the independent variable 'financial literacy' which impact was assessed;

n – the number of observations in the sample.

When using the correlation coefficients, we had taken into consideration the known fact that if both dependent and independent variables were in close relation with additional, third variable, that could produce biased estimates of the coefficients. In the particular case with financial literacy there already were priori information that it was closely related with the country's welfare (Disney & Gathergood, 2012; Lin & Bates, 2022) and on the other side the high-income countries were known to consume more goods and services, leading also to higher carbon footprint (Auffhammer & Wolfram 2014; Gertler et al., 2016; Caron & Fally, 2018). The country's development level thus could play an essential role in creating false correlations between financial literacy and carbon footprint. Elimination of such potential problems was performed by computing partial correlation coefficients with certain economic indicators used as control variables by the formula:

$$r_{xy.z} = \frac{r_{xy}-r_{xz}\times r_{yz}}{\sqrt{(1-r_{xz}^2)(1-r_{yz}^2)}} \quad (2)$$

where: z is the control variable.

The statistical significance of the estimated coefficients was assessed with the calculation of the *t-statistic*:

$$t = \frac{r\sqrt{n-2}}{\sqrt{1-r^2}} \quad (3)$$

which follows *t*-distribution with $(n-2)$ degrees of freedom and its associated significance level (*p-value*).

Measuring the influence of financial literacy on the carbon footprint was performed by building and estimating a regression model. The form of the model and its parameters allowed us to assess the direction, amplitude, and form of the impact of financial literacy on carbon emissions with accommodation of the control variables. An important moment when creating the model was a fact observed by Fakher (2019) when analyzing the ecological footprint's determinants in developing countries. Fakher (2019) established that the relationship between financial development and ecological footprint was non-uniform (non-linear) and followed a U-inverse form. To account for possible non-linearity in data, the regression model will be estimated in parabolic form:

$$y_i = a + b_1 x_i + b_2 x_i^2 + \sum_{j=1}^{k} c_j z_{i,j} + \varepsilon_i \quad (4)$$

where: y_i is the dependent variable representing the carbon footprint across the cross-section data;

x_i – the independent variable 'financial literacy' which impact was assessed;

$z_{i,j}$ – the control variables;

a, b_1, b_2 and c_j – parameters of the model;

k – the number of control variables;

ε_i – residuals from the regression equation which were supposed to behave like independent and identically distributed random variables with zero expectations and common variance.

The diagnostic checks of the model's residuals were concerned primarily with possible heteroscedasticity. As the countries all over the world are not random in the way of geography, economic development or growth, availability of resources, energy abundance and consumption, labor force, technological level, etc., it is common in econometric modeling of such data to find the residuals violating the requirement for common variance. When estimating their model, Ding et al. (2018) used geographically weighted regression to solve similar problems with the heterogeneity among the regions of China. In this study, we decided to scale variables with the size of the economy by using relative forms. Nonetheless, White heteroscedasticity tests (White, 1980) were run for all the models, and when necessary, the standard errors were corrected using the MacKinnon-White procedure (MacKinnon & White, 1985).

The data used in the study covered most of the countries in the world with some exceptions due to lack of information. The dependent variables representing carbon emission were used in three relative forms: CO_2 emissions per capita, per unit of energy and per unit of gross domestic product. The independent variable was financial literacy of the adult population. When selecting control variables, we took into consideration that in a comparable situation Zhang et al. (2021) used the control variables of "gross domestic product", "urbanization rate", "literacy rate", "youth life expectancy" when analyzing the relation between subjective well-being and quality of the environment. Thus, in our study we will account for the development level of the different countries by using as a control variable "gross domestic product per capita."

We must consider not only the direct influence that financial literacy could have on the carbon footprint but also the indirect influence (Popova et al., 2022). Howell (2018) presented three mechanisms that influence carbon literacy: energy monitoring, carbon footprint statements, and social learning through sharing information, skills, and resources. As the financial literacy could influence the carbon footprint (direct effect) or could be related to the carbon literacy that in its turn influence carbon footprint (indirect effect) those mechanisms could play their role in the relation and thus, must be accounted for in the current study. That is why besides data about financial literacy and carbon footprint, additional variables representing energy consumption and internet connectivity were included in the dataset. The former related to energy control, and the latter – to the sharing of information via the internet and social networks. In summary, the following variables were selected for the study:

x – Percentage of adults who are financially literate. Data were acquired in the large-scale study of Standard & Poor's in 2014. While there are other, more recent studies (e.g., International Survey of Adult Financial Literacy of OECD), they did not cover as many countries and were thus inappropriate for the analysis. The S&P Global Financial Literacy Survey was performed in cooperation with Gallup Inc., the World Bank Development Research Group and the Global Financial Literacy Excellence Center and covered more than 150000 individuals from 148 countries all over the world. The questionnaire addressed four basic aspects of financial education of the respondents: risk diversification, inflation, numeracy (interest), and compound interest. Responses were collected with either face-to-face or telephone interview. In the first case the sample was formed by multi-staged random selection and stratified by variables as population size of the basic units or geography. In the latter, simple random sampling was used to choose the respondents. The resulting data were weighted to ensure representative sample at national level. The main indicator of the survey was the 'Percentage of adults who are financially literate,' measured in percentage, and this variable was used in this study to measure financial literacy in the countries of the world. The time of the survey limited our analysis to 2014 but more recent years could be included in such analysis only when new data is acquired about financial literacy worldwide.

y_1 *– Emissions of carbon dioxide per capita*. The variable measures the average annual emissions per person for a country or region. It is computed by dividing the total annual emissions of that country or region by its total population.

y_2 *– Emissions of carbon dioxide per unit of Gross Domestic Product*. Variable stands for the carbon intensity level of a country's economy (aka 'carbon intensity of economies'). The data were computed by dividing the annual carbon dioxide emissions of a country by its annual gross domestic product.

y_3 *– Emissions of carbon dioxide per unit of energy*. Indicator measures how high carbon-intensive the energy mix of the country is. The metric was computed by dividing the annual emissions of the country by its primary energy consumption.

z_1 *– Gross domestic product per capita*. Measurement is Gross Domestic Product measured in international USD ($) using 2011 prices to adjust for price changes over time (inflation) and price differences between countries.

z_2 *– Primary energy consumption per capita*. The variable presents the intensity of energy use in a country, measured in kilowatt-hours per person per year.

z_3 – Primary energy consumption per unit of Gross Domestic Product. The variable measures the energy consumption in the country's economy, indicating the relation between energy consumption and economic development. The measurement unit is kilowatt-hours per international-USD ($) at 2011 prices.

The variables from y_1 through y_3, and z_1 through z_3 were acquired from the Our World in Data database (2023) for 2014 to be synchronized with the financial literacy.

z_4 – Individuals using the Internet. The information about internet connectivity was acquired from the World Bank. The indicator is named "Individuals using the Internet (% of population)" and represents the overall internet coverage and usage in the countries around the world. To match with the financial literacy data, the timing is also set at 2014. Information about the indicator was from the World Bank website (The World Bank, 2023).

There were minor differences among the datasets as some countries were not present in one of them or there were no data available for 2014. The intersection of all those sets gave us 137 countries in total that we used in the following analysis.

4. Results.

The connections between the financial literacy and all dependent and control variable can be observed in Figure 1.

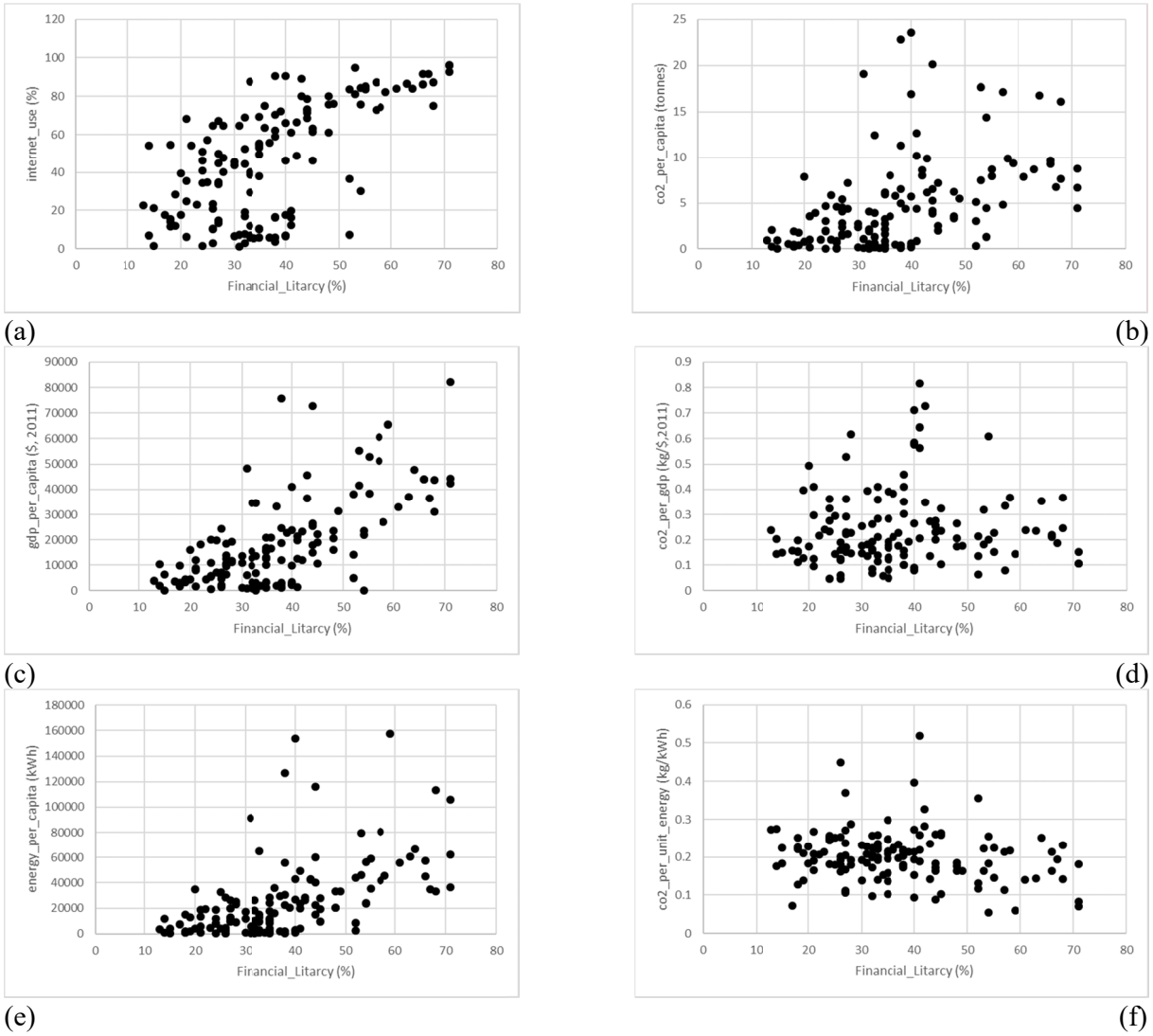

Fig. 1. Financial literacy, carbon emissions and control variables.

Source: based on authors' calculations.

The scatterplots showed that the relation between financial literacy on one side and internet use, gross domestic product per capita and energy per capita on the other were well presented in the shape of the dots-field. As expected, the visible features of the data revealed that the increase in financial literacy was associated with an increase in internet use, economic development and energy access and availability (Fig. 1-a, 1-c, and 1-e). The relation between financial literacy and carbon emissions was not so clear.

The dots were more dispersed, though not evenly. Even though there were some relationships, they were non-linear. Especially the symmetry in 1-d hinted at a possible parabolic link with an inverse U form.

In 1-b and 1-f, the inverse U form was not obvious as some skewness towards left or right impacted the fields of dots. The correlation and partial correlation coefficients between financial literacy and carbon emissions are presented in Table 1.

Table 1. Correlation coefficient between financial literacy and carbon emissions.

Indicators	Carbon Footprint Variables			Mechanics Variables			Control Variable
	co2_per_capita	co2_per_gdp	co2_per_unit_energy	energy_per_capita	energy_per_gdp	internet_use	gdp_per_capita
Correlation Coefficients	0.484	0.062	-0.200	0.554	0.183	0.631	0.658
Significance (t-stat)	**6.515**	0.731	**-2.410**	**7.843**	**2.190**	**9.591**	**10.314**
Partial Correlation Coefficients (control for gdp_per_capita)	-0.080	-0.027	-0.085	-0.054	-0.047	0.206	x
Significance (t-stat)	-0.941	-0.323	-1.010	-0.636	-0.559	**2.482**	x

Source: based on authors' calculations.

The simple bivariate correlation coefficients were significant with except for carbon emissions per unit of gross domestic product, reinforcing the decision to use gross domestic product as control variable. When its influence was removed in the partial correlation coefficients, they turned to be insignificant. The only significant correlation at 5% level was between financial literacy and internet use, though its value was smaller than the simple one.

In all other cases the values dropped, and many changed their signs. It was worth noting that all partial coefficients with carbon footprint variables and the first two mechanics variables become negative. The non-linear, and parabolic relation between financial literacy and carbon emissions are shown in Table 2 with the correlation and partial correlation coefficients computed using squared financial literacy and the same control variable "gross domestic product".

Table 2. Correlation coefficient between square of financial literacy and carbon emissions

Indicators	Carbon Footprint Variables			Mechanics Variables			Control Variable
	co_2_per_capita	co_2_per_gdp	co_2_per_unit_energy	energy_per_capita	energy_per_gdp	internet_use	gdp_per_capita
Correlation Coefficients	0.466	0.027	-0.223	0.558	0.173	0.636	0.658
Significance (t-stat)	**6.202**	0.319	**-2.699**	**7.933**	**2.076**	**9.711**	**10.314**
Partial Correlation Coefficients (control for gdp_per_capita)	-0.143	-0.077	-0.114	-0.074	-0.067	0.195	x
Significance (t-stat)	-1.707	-0.916	-1.358	-0.874	-0.796	**2.341**	x

Source: based on authors' calculations.

Again, many correlation coefficients were significant, but their partial counterparts were not. And again, their signs shifted to negative, with the only positive one being the partial correlation coefficient for the relation between squared financial literacy and internet use. This was the only one significant at 5% level. The changes in the others were in the amplitudes as all show higher association with squares of financial literacy than with financial literacy variable. The correlation coefficients gave valuable information that the relation between financial literacy and carbon footprint was weak, negative, and non-linear. The internet use is associated with the financial literacy at moderate, but statistically significant level (Tables 1-2).

Next step of the analysis was estimating three regression models, one for each carbon footprint variable (Tables 3-8). The independent and control variables were the same in all models with one exception – in the model with the dependent variable 'co_2_emissions_per_gdp' the control variable for the energy consumption was also changed to 'energy_per_gdp' instead of 'energy_per_capita' as in other two models. This was done for better synchronization with the dependent variable, that was scaled in the same way.

Table 3. Regression model results with dependent variable "co_2 emissions per capita".

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Intercept	-3.111804	1.207802	-2.576419	0.011100
Financial_Literacy	0.196807	0.070591	2.787981	0.006100
Financial_Literacy^2	-0.002745	0.000976	-2.811924	0.005700
energy_per_capita	0.000127	0.000034	3.780179	0.000200
internet_use	0.025346	0.018234	1.390087	0.166900
gdp_per_capita	0.000023	0.000041	0.564804	0.573200

Source: based on authors' calculations.

Table 4. Regression model diagnostic with dependent variable "co_2 emissions per capita".

R-squared	0.794
Adjusted R-squared	0.786
S.E. of regression	2.3303
F-statistic	100.2
Prob(F-statistic)	0
JB Normality Test	500.3
Prob (Chi-sq.-statistic)	0
WHITE Heteroskedasticity Test	11.8
Prob. F-statistic (19,116)	0

Source: based on authors' calculations.

Table 5. Regression model results with dependent variable "co_2 emissions per gdp".

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Intercept	-0.096853	0.060806	-1.592831	0.113700
Financial_Literacy	0.006945	0.003127	2.220686	0.028100
Financial_Literacy^2	-0.000084	0.000036	-2.359722	0.019800
energy_per_gdp	0.190011	0.022251	8.539364	0.000000
internet_use	0.000139	0.000681	0.203410	0.839100
gdp_per_capita	-0.000001	0.000001	-1.356151	0.177500

Source: based on authors' calculations.

Table 6. Regression model diagnostic with dependent variable 'co2_emissions_per_gdp'.

R-squared	0.615
Adjusted R-squared	0.599
S.E. of regression	0.0944
F-statistic	40.5
Prob(F-statistic)	0
JB Normality Test	283.1
Prob (Chi-sq.-statistic)	0
WHITE Heteroskedasticity Test	1.6568
Prob. F-statistic (19,113)	0.0546

Source: based on authors' calculations.

Table 7. Regression model results with dependent variable 'co2_emissions_per_energy'.

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Intercept	0.177098	0.037126	4.770186	0.000000
Financial_Literacy	0.002537	0.001991	1.274432	0.204800
Financial_Literacy^2	-0.000039	0.000023	-1.737992	0.084600
energy_per_capita	-0.000001	0.000000	-1.785516	0.076500
internet_use	-0.000055	0.000379	-0.144051	0.885700
gdp_per_capita	0.000001	0.000001	0.729612	0.466900

Source: based on authors' calculations.

Table 8. Regression model diagnostic with dependent variable 'co2_emissions_per_energy'.

R-squared	0.081
Adjusted R-squared	0.046
S.E. of regression	0.0663
F-statistic	2.307
Prob(F-statistic)	0.0480
JB Normality Test	126
Prob (Chi-sq.-statistic)	0
WHITE Heteroskedasticity Test	0.696
Prob. F-statistic (19,116)	0.8160

Source: based on authors' calculations.

The first model diagnostic showed that there was heteroscedasticity in the regression residuals, as the White test statistic was significant at 5% level. Therefore, the standard errors were corrected for it with the MacKinnon-White procedure. In the second and third models the White test showed no problem with heteroscedasticity as residuals could be treated to have common variance. In all models the residuals fail to fulfill the normality requirement as shown by the Jarque-Bera test statistic, that was significant at 5% level.

The dataset consisted of more than 100 observations, and thus, we could expect that the parameter estimates would be at least asymptotically normal. All models were adequate, as presented by the Fisher F-statistics; all of them were significant at the 5% level. They differed in their explaining power, though. The first model explained about 79% of the variation in carbon emissions per capita; the second explained around 62% of changes in carbon emissions per unit of gross domestic product; and the third explained only about 8% of the variability of carbon emissions per unit of energy.

When concerned with carbon emissions per capita, a considerable influence was recorded for financial literacy, its squared value, and energy consumption per capita. Energy impact was the stronger one – for every additional kilowatt-hour per person per year the carbon footprint per person grew by 0.127 kg, while the financial literacy's influence was mixed.

At lower levels, financial literacy supported an increase in carbon emissions, but at higher levels its influence reversed and started to decrease emissions. The parabolic nature of the relation was presented by positive velocity (0.197) and negative acceleration (-003). The turning point for those parameter values was about 35.8% financial literacy – for countries with less than 35.8% financial literacy effect was positive while for the ones with more than 35.8% financial literacy effect was negative (and beneficial for the environment). At the same time, the influence of internet connection and gross domestic product per capita was not significant at 5% level. The possible explanation of the first could be collinearity with financial literacy variable, while for the second – close relation with energy consumption per capita.

The results for the second model were almost identical. Financial literacy influence was parabolic with positive increase (0.007), negative acceleration (-0.00008), and turning point measured around 41.4% financial literacy, while the effect of energy consumption was the strongest – for every kilowatt-hour in energy consumption, the carbon emissions grew with 0.19 kg. Internet use and gross domestic product did not influence carbon emissions per unit of gross domestic product.

The third model represented the relation between carbon emissions per unit of energy and all variables. The only significant parameter was the constant, pointing out that energy was indeed the main contributor to the carbon emissions at almost constant rate for the different countries. Financial literacy influence (0.0025) was not significant at 5% level, but the squared financial literacy parameter (-0.000039) was significant at 10% level reinforcing the non-linear, parabolic nature of the relation with turning point around 32.4% financial literacy.

The models' results allowed us to make conclusion that *the hypothesis that financial literacy impacted the carbon emissions in 2014 worldwide had to be accepted*. Financial literacy indeed influenced carbon emissions in complex, non-linear way, with initial increase followed by decrease. The effect of energy consumption for carbon emissions was stronger than financial literacy and in the same direction – with the increase of the energy consumption carbon emission rise too.

The estimated models confirmed the statement of Fakher (2019) for a non-uniform relationship between financial development and the carbon footprint. The 2014 worldwide sample followed a U-inverse form. At low financial literacy observed in underdeveloped countries, the situation was not favorable for nature. As financial literacy there increased, welfare, income, and consumption, including energy consumption, increased too, leading to an increase of greenhouse gas emissions generated, i.e., bigger carbon footprint. The economic development of many such countries, especially in the case of underdeveloped countries, was inevitably related to consumption. In that manner, energy consumption was among the major factors influencing the production of greenhouse gas emissions. On the one hand, the growing consumer needs led to an increase in industrial energy consumption – to produce goods and services, the economy needed more energy, and on the other hand – improving the living standard of households led to an increase in households' energy consumption.

The situation was different in developed countries. Once a certain stage of economic development was reached (a high stage of development), the relationship was reversed, i.e., in developed countries financial literacy worked in the opposite direction towards reducing the carbon footprint and protecting the environment. This beneficial impact of high financial literacy could be contributed to three dimensions.

First, financial literacy improved access to quality education, including climate change and the impact of human activity on the environment. Knowledge itself was a key factor and major initial driver for climate action (Kolenatý et al., 2022). The popularization of climate knowledge and development of 'easy to reach and understand' science resources could significantly lower the energy consumption carbon footprint (Ding et al., 2018), while lack of both carbon education and climate change information resulted in social, economic, and environmental dissatisfaction (Uchehara, 2021).

Thus, increasing financial literacy was conducive to raising educational level and improving responsive sustainable behavior of consumers and entrepreneurs.

Second, financial literacy improved the population's ability to consume goods and services with a lower carbon footprint. Ecological carbon footprint was significantly negatively related to subjective well-being in developed countries. An increase in the amount of carbon footprint factors was associated with a country's degree of development (Zhang et al., 2021). The higher degree of development supposed better access to goods and services and enhanced options for making sustainable consumption decisions, which led to more responsible consumption, consumption of ecologically friendly products and services and lowering the carbon footprint.

Third, financial literacy improved well-being and thus facilitated access to the internet and mobile tools/apps that made it possible to assess an individual's carbon footprint and select different alternatives of goods and services according to their carbon footprint in a manner of lowering personal ecological carbon footprint.

According to Schrills et al. (2021), designing digital assistants to provide users with information about their CO_2 footprint could improve CO_2 literacy. Applications increased environmental literacy and motivated users to adopt more sustainable lifestyles (Scharl, et al., 2016).

While financial literacy impact was favorable in the advances in economic development there were also obstacles that decrease its beneficial influence and they were primarily linked with the insufficient focus on financial literacy vis-à-vis sustainable development goals and greenhouse gas emissions, i.e., it was not sufficiently linked to these phenomena (specific knowledge is better than general knowledge). Not only should the focus tolerate the specific, but it should also target specific groups e.g., entrepreneurs. According to Shiao et al., (2013), improving general education of building owners or users was important to their carbon reduction commitment.

5. Conclusions.

The study's aim was to estimate the connection between financial literacy and carbon emissions while accounting for the influence of economic development and energy consumption. The econometric models showed that energy consumption (both industrial and household consumption) was the most significant generator of greenhouse gas emissions in 2014. The authors' team also found that financial literacy and carbon footprint were connected, and the relationship between them was parabolic in U-inverse form with positive velocity and negative acceleration. Thus, while at lower levels of financial literacy it stimulated an increase in GHG emissions, after a certain level of economic development was reached, the relationship between financial literacy and carbon footprint led to a reversal of the impact. The turning points for different carbon footprint variables varied between 32.4% and 41.4% of the financial literacy rating as measured by the S&P Worldwide Study in 2014. The more economically developed a country was, the higher its financial literacy above the aforementioned turning points, and the lower its' carbon footprint. Thus, increasing financial literacy could be a powerful tool for reducing carbon footprints.

In achieving such a goal, it could be advocated to focus educational efforts not only in the general areas of financial literacy and sustainability but also in the more specific field of their intersection—sustainable financial literacy. Another possible approach is to emphasize financial literacy among specific target groups (entrepreneurs, small and medium-sized business owners, etc.), thus increasing understanding of sustainable financial literacy where it matters most. As inequality was already identified as a major barrier to the achievement of sustainable development (Siraj-Blatchford, 2016), it could be recommended to increase commitment in early childhood education for sustainable development to induce a significant contribution. The main road to meeting this challenge lies in raising income, as it would reduce the carbon footprint overall; i.e., reducing inequality leads slowly but steadily to a reduction in the carbon footprint.

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