Research Article

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Portfolio Allocation, Risk Aversion, and Digital Literacy Among the European Elderly

https://doi.org/10.1515/econ-2022-0072
received September 28, 2023; accepted February 05, 2024

Abstract: This study contributes to the literature on portfolio choices of elder persons by examining the influence of digital literacy on the propensity to own risky assets, when considering individual- and country-level variables. Our empirical analysis is based on data from Survey of Health, Ageing and Retirement in Europe and a set of macroeconomic indicators retrieved from international databases. To capture the impact of individual- and country-level factors, we have utilized multilevel models with a two-level sampling design. The results obtained provide evidence for a positive relationship between individual- and country-level digital literacy and portfolio riskiness, as well as heterogeneity in the portfolio choices of older individuals across the European Union (EU) countries. In addition, age is found to influence differently the portfolio riskiness of elder persons across the EU countries. Bridging the digital divide may provide access to balanced-risk portfolios for elderly persons.

Keywords: portfolio choices, stock market participation, digital divide, elderly people

JEL Codes: G11, F30

1 Introduction

The last two decades was marked by breakthroughs in information communication technologies (ICTs), which provided new opportunities for economic development all over the world, but especially in developing and developed countries. Despite the improvements in connectivity and enhanced productivity generated by technological improvements, persons who cannot utilize digital tools and platforms may be marginalized, suffering from different forms of the digital divide. The digital divide is prominent between younger and older persons since younger individuals are more experienced with technology and have grown up with more exposure to technology. Nevertheless, the digital divide can impede older individuals from undergoing important activities and benefiting from opportunities, including those related to personal finances and investments.

Retirement represents a phase of life when people often (re)consider investing in financial assets as an opportunity to simply increase the income replacement rate. However, the lack of digital skills may represent a burden, especially for elder persons, when purchasing financial assets and absorbing financial information. Consequently, the portfolio choices of individuals can be influenced in various manners by digital literacy, including the use of online trading platforms for processing buy and sell orders, the access and analysis of financial data using the internet for making informed decisions, as well as using the newly emerged robo-advisors.

The literature shows that the digital divide continues to represent a persistent issue in the European Union (EU), even though several efforts have been made to reduce the digital gap. The first-order digital divide is concerned with the access of individuals to ICT. The uneven access to ICT could determine the marginalization of individuals and communities (Elena-Bucea et al., 2021). However, the focus in the literature has shifted from the simple access to ICT to the skills of individuals and communities in using ICT, namely, the second-order digital divide, and the tangible outcomes of using technology (i.e., third-level digital divide). Several categories of citizens are more prone to lack digital skills and more vulnerable to being affected by the digital divide in the EU: older persons living in sparsely populated areas, especially older women, or elder individuals with a low level of education, little internet use, and a relatively low level of income (Botrić & Božić, 2021; Vasilescu et al., 2020).

The portfolio allocation of elder individuals was previously analyzed by various studies. The following determinants were considered to influence the propensity to own stocks, either directly or indirectly through mutual funds or retirement accounts: psychological factors (Angelini & Cavapozzi, 2017; Bucciol & Zarri, 2017; Georgarakos & Pasini,

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2011), cognitive abilities (Christelis et al., 2010), and the social network (Ostrovsky-Berman & Litwin, 2019). Other predictors that could influence the investment behavior of elder persons were considered, including the health status and the coverage of the healthcare system (Atella et al., 2012; Banks et al., 2020), as well as the existence of a life insurance policy (Cavapozzi et al., 2013).

Our research makes three distinct contributions to the literature. First, we examine the influence of digital skills at the individual level and country level on the portfolio riskiness of senior persons. To the best of our knowledge, the relationship between digital skills and portfolio choices of senior persons was not examined so far in the literature. Elderly persons represent a vulnerable category for ICT marginalization. Our empirical results suggest the access of older individuals to riskier financial assets might be improved by reducing the digital divide, which might subsequently create investment opportunities. Second, this article introduces novel variables in the empirical analysis at both individual and country levels, providing a starting point for policy formulation to reduce the digital divide. Finally, we combine data obtained from wave eight of Survey of Health, Ageing and Retirement in Europe (SHARE) with data from international databases, which enables us to identify the influence of digital literacy at the individual and country levels on portfolio riskiness.

The empirical analysis is conducted using multilevel models, more specifically two-level random intercept models with covariates, as well as a two-level random slope model. For the models, the likelihood ratio (LR) test establishes that the models are adequate compared to single-level models and models with fewer predictors. A similar result was reiterated by the Information Criteria (i.e., Akaike information criterion [AIC] and Bayesian information criterion [BIC]). The data from our empirical analysis are clustered at two different levels: individuals (Level 1) are nested in 25 EU countries (Level 2). The predictors utilized in the empirical analysis were based on theoretical considerations, including common socio-demographic control variables and variables indicating more recent forms of digital literacy.

The multilevel logistical models that we have applied enable us to depict the within- and between- country variation across the EU, as to finally identify heterogeneous interest in financial assets. Furthermore, we investigate the impact of age on portfolio riskiness across different countries by using random slopes for age in a multilevel logistic regression. The individual- and country-level data were retrieved from three datasets: (1) wave eight of the SHARE, which was collected in 2019/2020 (Börsch-Supan, 2022; Börsch-Supan et al., 2013); (2) Eurostat (Eurostat, 2023a,b); and (3) Digital Economy and Society Index (European Commission, 2022).

The rest of this article is organized as follows. Section 2 is dedicated to the analysis of the specialized literature. Section 3 introduces the databases and the methods that were used. Section 4 is dedicated to results and interpretations, while Section 5 is dedicated to conclusions and discussions.

2 Literature Review

2.1 Measures of the Digital Divide

The popularity of ICT increased exponentially in the last decades and various factors intensified its adoption. ICT has become a forefront of growth for humanity, and the societal reliance at the present and in the future on technology is undisputed. Despite the numerous benefits and subsequent potential for boosting productivity and reducing costs for companies, the evolution of ICT has been commonly associated with concerns regarding increasing disparities in its use and access.

Initially, the term "digital divide" was first utilized in the mid-1990s by Larry Irving, Jr., who served as the head of the National Telecommunications Infrastructure Administration (Çilan et al., 2009). The definition of "digital divide" given by OECD (2001) is still relevant and accurately defines this phenomenon as "the gap *between individuals, households, businesses and geographic areas at different socio-economic levels with regard both to their opportunities to access information and communication technologies (ICTs) and to their use of Internet for a wide variety of activities."* The term "digital exclusion" was also coined in the literature and indicates a complex and dynamic phenomenon (Van Dijk & Hacker, 2003). Both terms refer to the segregation of individuals regarding technology access and skills, which hinder reaping the benefits of technology.

The literature pertaining to the digital divide has shifted its focus over time. In the beginning, plenty of articles focused on the adoption of the internet, namely, if persons have access to the internet, being the indicator of foremost importance for measuring the digital divide (Botrić & Božić, 2021). This is commonly referred to as the first-order digital divide, addressing the lack of adoption, "have access to ICT" or "have not access to ICT," which is considered obsolete and imprecise (Riggins & Dewan, 2005; Warschauer, 2003). Subsequent studies were concerned with the frequency of use of the internet.

Beyond the access gap to ICT, a divide was identified regarding the skills and literacy among persons who

already have access to ICT, which is known as the "second-order digital divide" (Dewan & Riggins, 2005) or "second-level digital divide" (Friemel & Signer, 2010). This divide emphasized that how individuals, organizations, and countries use ICT should be also considered, beyond the simple access gap. The recurring factors that determine the presence of the second-level digital divide were analyzed for vulnerable population groups. Frequently, digital inequalities reflect offline inequalities, such as socioeconomic resources, physical abilities, and knowledge (Vassilakopoulou & Hustad, 2023).

Additional factors beyond socioeconomic factors that contribute to the digital divide were analyzed in the specialized literature, namely, a) motivation, b) personality traits, and c) digital skills. A large body of studies focuses on elder persons since they faced barriers to becoming familiar with technology, as opposed to younger individuals who grew up using technology since childhood. There is no established classification for persons who adhere to the definition of older or citizens since there exist different thresholds for grouping individuals based on their age: older adult age might correspond to individuals aged over 45 years (Czaja et al., 2013), over 51 years (Cotten et al., 2012; Silver, 2014), over 60 years (Lam & Lam, 2009), or over 65 years (e.g. Friemel, 2016; Gell et al., 2015; Quan-Haase et al., 2017).

The slow adoption of technology by the older population may be caused by the following key aspects, which the older themselves identified: negative attitude toward technology, fear, and anxiety when using digital services and technology, lack of knowledge, difficulties understanding digital terminology, as well as having a sense of being too old for learning (Holgersson & Söderström, 2019).

Various intervention methods have been identified to mitigate the barriers to using technology by elder persons. At the family level, having the support of the members of the family is essential in overcoming these hindrances and improving digital skills. The support of family can be either emotional, regarding patience, praise, comfort, and encouragement, which decrease technology anxiety, or cognitive support which facilitates the learning and development of digital skills (Xiong & Zuo, 2019).

Outside the family, the second-order digital divide can be reduced by designing adequate policy interventions. For instance, employers could take greater responsibility for the IT education of the employees when they are close to retirement since employment has a central role in explaining the usage of e-government services (Sipior et al., 2011). Therefore, the prevention of digital exclusion may be achieved by developing the digital skills of seniors before retirement (Rockmann et al., 2018). The mitigation of digital gaps can be attained through proper training and education (Van Dijk, 2012).

The third level of digital inclusion was labeled in the literature as the "third-level digital divide," which focused on the investigation of tangible outcomes rather than skills and simple usage (Van Deursen & Helsper, 2015). The disparities in the third level of digital inclusion are considering the social and cultural benefits derived from using and accessing the technology, rather than just having the necessary skills and access, as in the previous levels.

2.2 Portfolio Allocation of Elder Persons

A rich theoretical and empirical body of literature focused on various determinants of household portfolio choices of elder persons, including the decision to hold financial assets and the share of given assets to the whole portfolio. Determinants such as psychological factors, cognitive abilities, health status, the coverage of the healthcare system, the existence of a life insurance policy, and the presence of an endowment were predominantly considered in the specialized literature.

There is a large body of literature examining the impact of psychological factors on the propensity to own stocks. For instance, the relationship between dispositional optimism and stock market participation was examined using the second wave of SHARE for 12 European countries, and it was discovered that optimism is positively related to the probability of stock ownership and the percentage of wealth invested in stocks (Angelini & Cavapozzi, 2017). Multiple studies analyzed the relationship between the Big Five personality traits and household financial decisions. Brown and Taylor (2014) found that unsecured debt and savings correlate with some Big Five personality traits, namely, Conscientiousness, Extraversion, and Agreeableness. The correlation between specific asset classes and personality traits was examined in the same study, and a negative correlation was identified between stock ownership and Extraversion (for couples) and Agreeableness (for single persons). Bucciol and Zarri (2017) argued that three personality traits are negatively correlated with financial risk-taking: Anxiety, Agreeableness, and Cynical Hostility using waves of the US Health and Retirement Study (HRS). In another study using Finnish data to examine the link between personality traits (and facets) and stock market participation, harm avoidance was identified to negatively correlate with stock ownership (Conlin et al., 2015). Georgarakos and Pasini (2011) stated that trust and sociability play distinct roles in stock market participation and should

be considered when analyzing households' stock market participation.

The impact of cognitive abilities on the inclination of individuals to invest in stocks was also investigated in the literature. The association between cognitive abilities and direct stock market participation and indirect participation through retirement accounts or mutual funds is a common finding in the literature (Christelis et al., 2010). More specifically, the association was driven by information constraints since less information-intensive assets were less strongly related to cognitive abilities. The social network is another relevant predictor for investing in risky assets. Stock ownership is positively correlated with the size of the social network, and the components of the social network are also important in the investment decision-making process (Ostrovsky-Berman & Litwin, 2019).

The investment behavior of older persons was found to be influenced by other factors, including health status and the coverage of the healthcare system. The perceived health status is more important than the objective health status in establishing portfolio decisions (Atella et al., 2012). Older individuals are less likely to own risky assets, health changes, and other life events influencing portfolio riskiness (Banks et al., 2020). The influence of the presence of a life insurance policy was also examined in the literature, and individuals with life insurance are found to be more likely to own stocks or invest in mutual funds (Cavapozzi et al., 2013).

3 Data and Methods

3.1 Data

We have conducted our empirical analysis using individual- and country-level data from three datasets: (1) wave eight of the SHARE, which was collected in 2019/2020; (2) Eurostat; and (3) Digital Economy and Society Index. A short description of data and variables of interest is provided below. In the SHARE dataset, the persons eligible to participate in this survey consisted of persons aged 50 years and over at the time of sampling and who had their domicile in the analyzed SHARE country (i.e., persons born before 1969 at the time of the interview). The data comprised in the SHARE database include microdata about socioeconomic status, health, as well as social networks in various European countries, creating a cross-national panel database.

Our sample included 42,584 individuals from 25 EU countries: Austria, Germany, Sweden, Netherlands, Spain, Italy, France, Denmark, Greece, Belgium, Czech Republic, Poland, Luxembourg, Hungary, Slovenia, Estonia, Croatia, Lithuania, Bulgaria, Cyprus, Finland, Latvia, Malta, Romania, and Slovakia. We have excluded from our analysis the other countries that were available in the SHARE database: Israel and Switzerland. We focused our attention on the EU countries since they adhere to the same political and economic framework, sharing common characteristics, allowing us to investigate individual- and group-level effects.

Financial and real assets have a dedicated section in the SHARE database, which includes information about various types of investments. More specifically, respondents are asked if they (a) have stocks, (b) have bonds, (c) have mutual funds, (d) have individual retirement accounts, and (e) have contractual savings. For respondents who invested in mutual funds or individual retirement accounts, they were further asked if mutual funds/individual retirement accounts are invested: (i) mostly in stocks, (ii) half in stocks half in bonds, and (iii) mostly in bonds. Using the financial information from the SHARE database, we have constructed a proxy that measures the investment profile of investors, by respecting the portfolio allocation methodology of Atella et al. (2012). The authors established this classification by following the literature on portfolio allocation (Brunetti & Torricelli, 2010; Guiso et al., 2002; Rosen & Wu, 2004). We have created an ordinal categorical variable measuring the portfolio riskiness, which ranges from values 1 to 3, where 1 corresponds to a safe allocation (contractual savings), 2 represents a moderately safe allocation (having bonds and not having stocks/mutual funds invested half in stocks and half in bonds or mostly in bonds/retirement accounts are invested half in stocks and half in bonds or mostly in bonds), 3 represents a risky allocation (having stocks and not having bonds and not having contractual savings/mutual funds are invested mostly in stocks and not having bonds and not having contractual savings/retirement accounts are invested mostly in stocks and not having bonds and not having contractual savings).

In addition to the SHARE database, we have also used Eurostat data, which captures country-level economic, poverty, and education conditions. We have also obtained country-level data regarding digital skills from the Digital Economy and Society Index (DESI). The European Commission assesses the digital progress of the EU's member countries through DESI, which includes multiple key components: digital skills, digital infrastructure, digital transformation of businesses, and digitalization of public services. Each category entails various indicators.

Table 1 depicts the summary statistics of the dataset. The sample statistics provided illustrate that the average age of respondents was 70 years old, and the majority of

respondents were female (57%), while only 16.3% of respondents were still employed or self-employed.

The individual-level variables are explained below. Portfolio riskiness is an ordinal categorical variable where 1 represents safe investments, 2 fairly-safe investments, and 3 risky investments. Life satisfaction is measured on a 0 to 10 scale, where 10 corresponds to the highest life satisfaction. Risk aversion is measured on a 0–4 ordinal scale, where the highest risk aversion is 4. Computer skills are measured on a 0–5 ordinal scale, where the highest value corresponds to excellent computer skills. Use of the internet in the past 7 days, gender, age, and years of education are other explanatory variables. The last four variables from Table 1 are country-level variables and are expressed in %.

3.2 Methods

The methodological approach utilized in this study includes multilevel (hierarchical or mixed effects) models, which allow the analysis of data with nested structures. The clustering of data in our analysis is based upon two different levels: individuals (Level 1) who are nested in 25 EU countries (Level 2). The adequacy of using multilevel models in our empirical research was established after running specific tests, to identify if the data exhibit a high degree of clustering (Steele, 2008).

In all configurations of the models that we have applied, the response variable represents a proxy that we have constructed and measures the investment profile of investors, by respecting the portfolio allocation methodology of Atella et al. (2012), which is consistent with previous studies regarding capital allocation.

First, we started our analysis with the simplest multilevel model that permitted us to identify the country effects on the investment profiles of individuals, without explanatory variables, which is also recognized as a "null multilevel model";

$$y_{ij} = \beta_0 + u_{0j} + e_{ij}, \tag{1}$$

where y_{ij} is the capital allocation proxy based on the three risk profiles that we have created, β_0 is the overall mean across countries, u_{0j} is the effect of country j on the capital allocation, and e_{ij} is an individual-level residual. The subscript i corresponds to an individual, while the subscript j corresponds to a country. The country effects u_{0j} are also referred to as country (or level 2 residuals), which we suppose to follow a normal distribution with mean zero and variance σ^2_{u0}. The estimation method for this regression was maximum likelihood.

To identify whether the multilevel models are justifiable in our empirical research, we have applied another null single-level model by removing the random country effect:

$$y_{ij} = \beta_0 + e_{ij}. \tag{2}$$

To identify whether the multilevel models better fit the data, we have utilized the LR test, where we have compared the null multilevel model with a null single-level model, at the 5% threshold. We have identified overwhelming

Table 1: Summary statistics of the dataset

Variables	Full sample				Female		Male	
	Mean	Std. dev.	Min	Max	Mean	Std. dev.	Mean	Std. dev.
Sample size	42,584				24,276		18,308	
Individual level								
Portfolio riskiness	0.3522	0.8668	0	3	0.3047	0.8009	0.4154	0.9435
Life satisfaction	7.5578	2.1788	−2	10	7.5275	2.1511	7.5980	2.2144
Risk aversion	3.6379	0.9379	−2	4	3.6983	0.8785	3.5598	1.0043
Computer skills	1.3684	1.4649	0	5	1.3591	1.4550	1.3805	1.4779
Use of internet in past 7 days	0.5441	0.4981	0	1	0.5282	0.4992	0.5652	0.4957
Years of education	10.839	3.8538	−3	25	10.609	3.9851	11.136	3.6558
Male or female	1.5700	0.4951	1	2	2	—	1	—
Age	70.649	9.0497	55	103	70.637	9.2319	70.666	8.8025
Country level								
Real gross domestic product (GDP)/capita growth rate (%)	0.0234	0.0148	0.0024	0.0492	—	—	—	—
Above basic level of digital skills (for persons aged 55–74, %)	0.1248	0.0649	0.0264	0.2779	—	—	—	—
Ordering online (%)	0.6065	0.1632	0.2171	0.8415	—	—	—	—
Severely materially and socially deprived (%)	0.0598	0.0539	0.014	0.245	—	—	—	—

evidence that supports the application of the multilevel model by carrying out a LR test. Furthermore, rather than solely relying on the LR test that suggested the full model specifications, we have calculated the Information Criteria (i.e., AIC and BIC) in a pairwise manner. The results of AIC and BIC indicate a negligible difference between the model in the full specification against the models with fewer country-level predictors, which support the full specification of the random intercept model, alongside the theoretical justification and the LR test (Table A1).

The null two-level model will be gradually enriched by adding predictors for the random intercept model and by allowing age to have a random slope in another model. The LR test will be used to examine whether the additional variables are appropriate.

To further analyze the heterogeneous impact of age across the sample countries, we have allowed age to have a random slope in another model, where we have reduced the number of predictors to avoid overparametrization and to highlight the role of age. This random slope model includes the individual and country-level covariates and is derived from the following equation:

$$y_{ij} = \beta_0 + \beta_1 x_{ij} + u_{0j} + u_{1j} x_{ij} + e_{ij}, \quad (3)$$

which can be rewritten in the following form:

$$y_{ij} = \beta_{0j} + \beta_{1j} x_{ij} + e_{ij},$$
$$\beta_{0j} = \beta_0 + u_{0j},$$
$$\beta_{1j} = \beta_1 + u_{1j}, \quad (4)$$

where the random effects u_{0j} and u_{1j} are assumed to follow a normal distribution with zero means, variances, σ^2_{u0} and σ^2_{u1}, respectively, and covariance σ_{u01}. The average regression line or the grand mean slope is β_1, while the slope of the line for country j is $\beta_1 + u_{1j}$.

4 Results and Interpretations

The empirical analysis aims to explain older people's portfolio riskiness upon a set of individual- and country-level predictor variables, and to also find out which of the two types of variables has a higher explanatory power. To accommodate both individual- and country-level variables, the multilevel analysis is first considered to be used here. However, we first run a series of tests to check the appropriateness of this methodology.

The variance partition coefficient (VPC) is used in multilevel modeling to partition the variation in a dataset within groups or between groups and to suggest whether a multilevel model is adequate, as opposed to a single-level model. The VPC for this regression is 0.122, which indicates that 12.2% of the variance in capital allocation can be attributed to differences between countries. The proportion of the total (residual) variance in the underlying propensity to have high interest in risky assets is attributable to differences between EU states. Aside from the VPC, we have applied LR tests, which established that a random intercept model fits better the data compared to a single-level model.

Table 2 reveals the empirical results we have obtained by applying a variance components model compared to two random intercept models. The first random intercept model includes only individual-level variables, while the second random intercept model includes both individual- and country-level variables. For the random intercept models, portfolio riskiness was regressed on the set of variables that we have explained, and the coefficients of both models are similar and the direction of relationships between the predictors and the response variable is the same.

In Model 3 of Table 2, the following country-level explanatory variables are added: national economic growth (variable real GDP/capita growth rate) and above the basic level of digital skills (for persons aged 55–74). By running LR tests, we have established that adding the extra parameters for random intercepts was not worthwhile and we present therein the results without random intercepts for those variables.

The relationship between portfolio riskiness and life satisfaction is found to be statistically significant and positive, which indicates that the propensity of individuals to invest in the stock market is higher if the persons are satisfied with their lives. There are various channels through which life satisfaction might affect financial risk tolerance and the willingness of individuals to invest in risky assets (stocks). First, this relationship may be attributable to the fact that individuals with high life satisfaction might have a good financial situation, which could be measured by income/pension or wealth. This result is consistent with previous studies from the specialized literature, which argued that the impact of economic circumstances was underestimated and economic factors significantly impact happiness (Headey et al., 2008; Powdthavee, 2010). Therefore, a lack of life satisfaction might correlate with a lack of financial resources, implying that individuals who are not satisfied might not have the disposable funds to invest in risky assets.

Second, persons who are not satisfied and happy with their lives may exhibit regret, including financial regret. Previous studies from the specialized literature have identified that the inclination for regret and happiness in life

has been identified to influence financial risk tolerance. If one individual experiences regret with a particular type of investment, then the tendency to make a similar investment is reduced (Bailey & Kinerson, 2005).

Risk aversion had a negative impact on portfolio riskiness, which is an anticipated and logical result, indicating that individuals with a higher risk aversion are less likely to invest in risky portfolios, which include directly or indirectly owned stocks. General risk aversion was previously identified to negatively affect risky investment preferences (Dinç Aydemir & Aren, 2017).

More importantly, computer skills and use of the internet in the last 7 days were both positively correlated with portfolio riskiness and the relationships were statistically significant, indicating that individuals with better digital skills were more inclined to include stocks directly in their portfolios or indirectly through mutual funds or individual retirement accounts than individuals who lacked digital skills and did not use the internet. This may be attributable to the necessary digital skills required to directly invest in stocks, since currently most of the trading is conducted online, either via the website of the broker or by using a mobile app. The buy/sell orders are processed online, which may impede older persons from trading if they do not possess digital skills or lack an internet connection. As far as indirect stock ownership is concerned, computer skills are required to invest in mutual funds too.

The impact of computer skills was further analyzed at the country level. The variable denoting the above basic digital skills (for persons aged 55–74 old) has a positive impact on the portfolio riskiness and is also significant at the 0.01 threshold. Individuals who have above basic digital skills are more prone to own risky assets (stocks) compared to individuals who lack such skills. This result provides

Table 2: Regression output for variance components model vs. random intercept models

Variables	(1) Variance components model	(2) Random intercept model I	(3) Random intercept model II
Individual-level variables			
Life satisfaction	—	0.00913***	0.00918***
		(0.00337)	(0.00336)
Risk aversion	—	−0.0371***	−0.0365***
		(0.00771)	(0.00771)
Computer skills	—	0.0191***	0.0185**
		(0.00728)	(0.00728)
Use of internet in the past 7 days	—	0.0677***	0.0638***
		(0.0214)	(0.0214)
Years of education	—	0.0155***	0.0154***
		(0.00208)	(0.00208)
Male or female	—	−0.0117	−0.0110
		(0.0137)	(0.0137)
Age	—	0.000893	0.000773
		(0.000859)	(0.000859)
Country-level variables			
Real GDP/capita growth rate	—	—	3.212
			(2.426)
Above basic level of digital skills (for persons aged 55–74)	—	—	2.726***
			(0.623)
Ordering online	—	—	−0.187
			(0.319)
Severely materially and socially deprived	—	—	−0.0782
			(0.571)
Random-effects parameters			
var(_cons)	0.09046	0.02594	0.00842
var(Residual)	0.64971	0.41461	0.41454
Observations	9,173	9,173	9,173
Number of groups	25	25	25

Standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. [Note: The first model is also known as a "null" multilevel model. Model (2) omits country-level variables, while model (3) includes both individual- and country-level variables.].

further evidence of the presence of a relationship between digital skills and portfolio allocation among older individuals. Opening a brokerage account, using mobile banking, and performing stock market orders require at least basic digital skills; therefore, the variable utilized in this analysis is based on theoretical foundations.

The standard socio-demographic indicators are included in the list of control variables: age, gender, and education, following the existing practices from the literature. The relationship between portfolio riskiness and education is positive and statistically significant. Several studies support a positive correlation between financial risk tolerance and the level of education (Faff et al., 2009; Grable, 1997; Grable & Joo, 2004). Individuals with a higher level of education may be more prone to taking financial risks and investing in riskier assets. One channel that may explain this relationship might be the level of earnings, which is positively correlated with education (Tamborini et al., 2015). Variables indicating the age and gender of persons were not statistically significant.

The national economic growth (variable real GDP/capita growth rate) is found to have a non-significant relationship, which is also the case for the following country-level variables: ordering online and severely materially and socially deprived. Ordering online was considered in the analysis since it reflects a more recent form of the digital divide that concerns the results of using ICT. The country-level variable of severely materially and socially deprived was included in the analysis from theoretical considerations. As expected, a negative relationship was identified between material and social deprivation and portfolio riskiness.

We have increased the number of covariates for robustness testing using variables based on theoretical considerations and variables used in previous studies in the literature. Therefore, we included in the models' specifications variables related to income (i.e., payments from old age, early retirement, survivor pensions, total household income) and cognitive abilities (i.e., self-rated reading skills; self-rated writing skills, score of verbal fluency test). The digital variables are still statistically significant after the inclusion of the income and cognitive variables. The results of the robustness testing are included in Table 3. As expected, individuals with larger payments from old age, early retirement, and survivor pensions are more likely to invest in riskier assets at the 0.01 threshold, which is also the case for the total household income variable. The relationship is also positive and statistically significant between portfolio riskiness and the following cognitive-related variables: self-rated reading skills and scores on verbal fluency tests. The relationship between cognitive abilities and stockholding was investigated in the literature. Christelis et al. (2010) provided evidence for a strong association between cognitive abilities and stockholding using the SHARE database. The mechanism through which reading skills and verbal fluency influence portfolio riskiness may be related to the absorption of financial information or the spread of information in the social network. The size of the social network was identified to be a relevant predictor for stockholding among the European elderly (Ostrovsky-Berman & Litwin, 2019).

To further examine the differences between countries regarding the interest of individuals in financial assets, we have analyzed the residuals of the variance components model. Figure 1 shows the estimated residuals for the EU states based on the variance components model. For a substantial number of states, the 95% confidence interval does not overlap zero, indicating that interest in financial assets is above average (above the zero line) or below average (below the zero line) at the 5% level for these states.

The list of the residual rank for each country from the EU is illustrated in Table 4, indicating how countries are situated compared to the baseline level regarding the risk aversion for financial assets. The most risk-averse countries are Latvia, Romania, and Bulgaria, indicating that the interest for financial assets is considerably below average. Those countries exhibit financial risk aversion, and individuals from those countries are more prone to invest in safer assets (saving accounts) rather than to invest in stocks directly or indirectly. Nordic countries such as Sweden, Denmark, and Finland are the countries that are the least financially risk-averse, and individuals are willing to invest in financial assets such as stocks. Other studies have identified significant stock ownership differences between stock market participation across EU countries. It has been argued that stock market participation is relatively high in Nordic countries since financial markets and institutions are more developed (Angelini & Cavapozzi, 2017). Countries within the EU exhibit a stark contrast in their capital allocation. Microdata analysis showed that the stock market participation of individuals with a low wealth in Sweden and Denmark is twice those of wealthy individuals from Austria, Spain, and Italy (Georgarakos & Pasini, 2011).

We further examined the age effect on portfolio riskiness across the EU countries. To establish that, we have fitted a random slope two-level ordered logistic regression where the portfolio riskiness was the response variable, as in the previous regressions, where we have introduced a random slope for age. The sole purpose of the model was to analyze whether the impact of age is different across the sample countries; therefore, we have reduced the number of predictors to achieve model convergence and avoid overparametrization. The working variable was included

Table 3: Robustness testing for other covariates regarding income and cognitive abilities

Variables	(1) Robustness testing for payments from old age, early retirement, and survivor pensions	(2) Robustness testing for cognitive abilities	(3) Robustness testing for total household income
Individual-level variables			
Life satisfaction	0.00865***	0.00635***	0.00603***
	(0.00151)	(0.00154)	(0.00154)
Risk aversion	−0.0366***	−0.0361***	−0.0354***
	(0.00345)	(0.00345)	(0.00345)
Computer skills	0.0186***	0.0148***	0.0144***
	(0.00325)	(0.00329)	(0.00329)
Use of internet in the past 7 days	0.0646***	0.0603***	0.0589***
	(0.00955)	(0.00958)	(0.00958)
Years of education	0.0155***	0.0135***	0.0129***
	(0.000931)	(0.000971)	(0.000976)
Male or female	−0.00997	−0.0127**	−0.0115*
	(0.00612)	(0.00615)	(0.00615)
Age	0.000720*	0.00124***	0.00127***
	(0.000384)	(0.000391)	(0.000391)
Payments from old age, early retirement, and survivor pensions	1.46×10^{-5}***	1.44×10^{-5}***	1.33×10^{-5}***
	(2.40×10^{-6})	(2.40×10^{-6})	(2.40×10^{-6})
Self-rated reading skills		0.0189***	0.0188***
		(0.00590)	(0.00589)
Self-rated writing skills		−0.0343***	−0.0337***
		(0.00583)	(0.00582)
Score of verbal fluency test		0.00211***	0.00207***
		(0.000461)	(0.000461)
Total household income			9.69×10^{-7}***
			(1.59×10^{-7})
Country-level variables			
Real GDP/capita growth rate	3.492*	3.418	4.000*
	(2.097)	(2.111)	(2.190)
Above basic level of digital skills (for persons aged 55–74)	2.768***	2.788***	2.722***
	(0.625)	(0.630)	(0.655)
Ordering online	−0.149	−0.181	−0.237
	(0.289)	(0.291)	(0.303)
Severely materially and socially deprived	0.0683	0.0688	0.00735
	(0.560)	(0.564)	(0.586)
Random-effects parameters			
var(_cons)	0.0106414	0.0108193	0.011768
var(Residual)	0.4134632	0.4128131	0.4124639
Observations	45,865	45,865	45,865
Number of groups	25	25	25

Standard errors in parentheses.
***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

to identify the influence of employment on the investment behavior of elder persons. The results of the model with a random slope for age are illustrated in Table 5.

We have maintained a variable related to digital skills since we were interested in determining the influence of country-level digital literacy on investment riskiness.

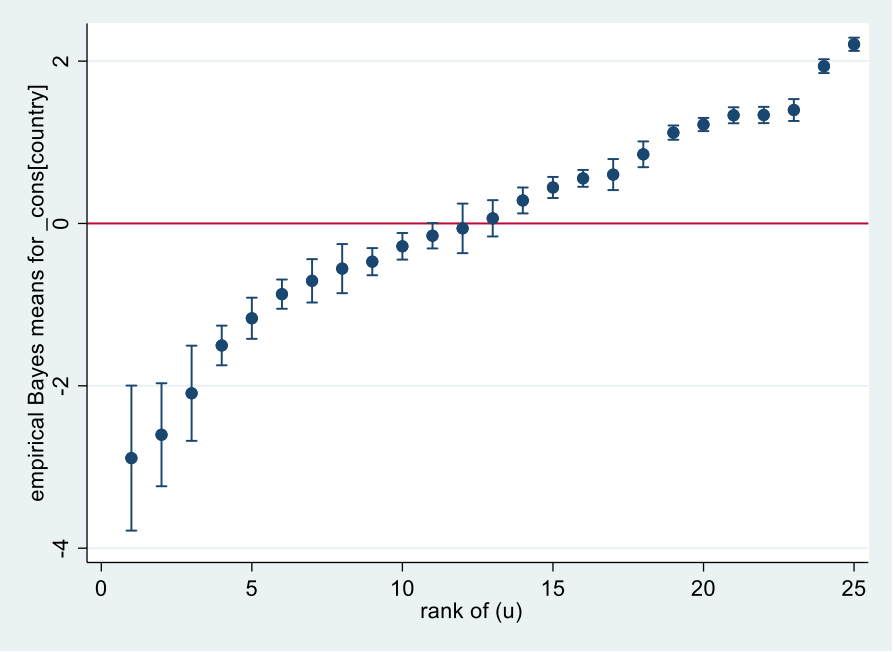

Figure 1: Residual estimates based on two-level variance components ordinal logistic model. [Note: The country effects are in rank order together with a 95% confidence interval. The horizontal red line (at 0) represents the average country in the data].

Table 4: Residual rank for the 25 EU member states based on the two-level variance-components ordinal logistic model

Residual rank (urank)	Country	Residual (u)
1	Latvia	−2.890016
2	Romania	−2.602614
3	Bulgaria	−2.091485
4	Greece	−1.502938
5	Poland	−1.167843
6	Estonia	−0.870634
7	Croatia	−0.7063709
8	Hungary	−0.5562575
9	Slovenia	−0.4705018
10	Italy	−0.2812563
11	Spain	−0.1510558
12	Cyprus	−0.060284
13	Slovakia	0.0636038
14	Lithuania	0.2835576
15	Netherlands	0.4435831
16	Czech Republic	0.5556223
17	Malta	0.6021659
18	Luxembourg	0.852118
19	France	1.119149
20	Germany	1.21891
21	Belgium	1.332912
22	Austria	1.3361
23	Finland	1.397493
24	Denmark	1.937838
25	Sweden	2.207618

Table 5: Ordered logistic regression with a random slope for age

Variables	(1) Portfolio riskiness
Age	−0.0170***
	(0.00386)
Life satisfaction	0.103***
	(0.00850)
Above basic level of digital skills (for persons aged 55–74)	8.317***
	(2.543)
Working	0.302***
	(0.0429)
Severely materially and socially deprived	−9.788***
	(2.960)
Observations	41,985
Number of groups	25

Standard errors in parentheses.
***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

Maximum likelihood was used as an estimation method for the coefficients and the cut points.

The results of the LR test indicate that the addition of a random slope for age is justified at the 0.01 threshold and the age effect varies across countries, and this specification captures the relationship better than a model without the random slope for age.

The model indicates a negative and statistically significant relationship between age and portfolio riskiness, indicating that older individuals are less prone to invest in risky assets compared to younger persons. This is consistent with previous findings in the literature, and age may influence the propensity to own stocks through multiple channels. Elder persons normally encounter higher health risks compared to younger individuals, which may determine them to be more risk-averse. The current health status and the expected health status negatively influence the proportion of risky assets (Edwards, 2008). The increased health risks of elder persons may cause them to reduce their allocation of capital toward risky assets. Older persons are likely to face higher future medical expenditures compared to younger persons. Poor health and risky asset ownership were found to be negatively related (Rosen & Wu, 2004). Another plausible explanation for the risk aversion of older persons is that their investment horizon is shorter compared to younger investors, who have a longer timespan to recover losses.

The relationship between life satisfaction and the response variable is positive and statistically significant in the random slope model for age and in the previous models. The positive correlation and the statistical significance are maintained also for the variable denoting the above basic level of digital skills. The variable of material and social deprivation maintains a negative correlation to portfolio riskiness, as in the previous models.

The influence of age on the investment behavior of older individuals between the countries from the sample was examined. We have introduced this analysis based on theoretical considerations considering expected heterogeneity across the EU states, namely, that the varying economic conditions, cultural norms, and regulatory frameworks can influence retirement investment behavior. From a practical perspective, understanding the manner age influences the investment behavior during the retirement phase across the EU states is necessary for establishing adequate policies by policymakers. The results of the models can serve as information for tailoring retirement planning policies or financial education programs to specific age groups and regions, to promote healthy financial behavior during retirement.

The age slopes were plotted against the country intercepts in Figure 2, based on the ordered logistic regression with a random slope for age. The coefficients of age in the random slope model indicate that age impacts differently the investment behavior across the EU countries. The countries in the top-left quadrant are countries that had lower-than-average portfolio riskiness but better-than-average participation as age increases. For instance, the most prominent differences in investment behavior when age is considered are present in France, indicating that if age increases, individuals are more willing to own risky assets, namely, stocks. Other countries such as Malta, Hungary, Luxembourg, Cyprus, Greece, Germany, and Finland are

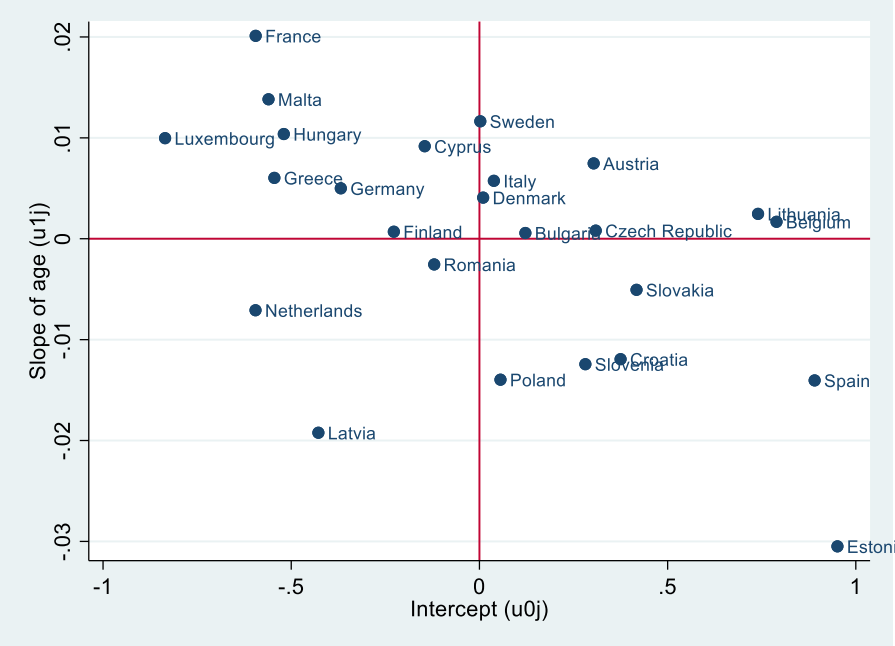

Figure 2: Age slopes versus country intercepts.

all in the same group. For the aforementioned countries, age has a positive impact on the propensity to own risky assets.

In the bottom-left quadrant are present countries with below-average mean portfolio riskiness with below-average slopes. This category includes Romania, the Netherlands, and Latvia. The interest for risky assets in these countries was lower than the mean and the inclination to own shares decreased as individuals aged.

For all the other countries in the right quadrants, the portfolio riskiness was higher than the average, with age having a positive impact on portfolio riskiness for the countries situated in the top-right quadrant, and a negative impact for the ones in the bottom-right quadrant.

5 Discussion and Conclusions

This study examined the propensity of older persons to invest in risky assets considering their digital skills, using individual- and country-level data from SHARE, Eurostat, and the Digital Economy and Society Index.

Our contribution to the literature is threefold. First, it extends the literature on portfolio allocation among elder individuals by investigating the influence of digital skills at individual and country levels on portfolio riskiness. To our knowledge, the impact of digital skills and the propensity to own risky assets have not been considered yet by research articles. The empirical findings suggest that reducing the digital gap might improve the access of older individuals to riskier financial assets, which may, in turn, create investment opportunities. Second, the introduction of novel variables into the empirical analysis at the individual and country levels might serve as a starting point in policy formulation for interventions to reduce the digital gap. Third, we have combined data retrieved from wave eight of SHARE with data from international databases, which permitted us to portray the impact of digital skills at the individual level, as well as the country level, on portfolio preferences.

Our study is particularly relevant since it explores the relationship between the digital skills of senior citizens and portfolio riskiness in the EU, using a methodological framework that permits us to analyze the differences across countries, which is necessary for policy interventions. Furthermore, the global context in which the population ages and the life expectancy increases implies that senior citizens comprise a growing percentage of the total population and the potential users of ICT. Consequently, persons spend a longer period of their lives as senior citizens, which indicates the necessity of acquiring digital skills and updating them, to bridge digital gaps and ensure well-being, including financial well-being.

The appropriateness of the methodological framework was considered after running LR tests and examining the VPC, which indicates clustering effects across the EU countries. The tests were in favor of multilevel models and suggested the specifications with a random intercept for the country and a random slope for age. The presence of covariates in our model was indicated by the LR tests compared to a null multilevel model.

Our results suggest the presence of positive and statistically significant relationships between digital skills and portfolio riskiness, indicating that individuals with digital skills are more prone to invest in risky assets, namely, stocks, either directly or indirectly. Both individual-level variables that considered digital skills were statistically significant: computer skills and the use of the internet in the past 7 days. A similar result was obtained for the country-level variable denoting the above digital skills, which had a positive impact on portfolio riskiness. The results are consistent with our expectations since digital skills are required to absorb financial information and participate in the stock market.

Moreover, the interest in risky financial assets in the EU was heterogeneous. The lowest interest for risky financial assets was observed in Latvia, Romania, and Bulgaria, while Nordic countries such as Finland, Denmark, and Sweden were the least financially risk-averse and more likely to participate in the stock market. Previous studies from the literature have identified high participation in the stock market in Nordic countries (Angelini & Cavapozzi, 2017; Georgarakos & Pasini, 2011).

Another empirical finding suggests that age influences differently the investment behavior of individuals across the EU countries, based on the results of the regression with a random slope for age. Even though age has a heterogeneous impact on portfolio riskiness across the EU sample countries, the overall coefficient for age is negative, namely, that as individuals age, their risk appetite is decreased, and they are less willing to invest in the stock market. This behavior can reinforce the assumptions of the life cycle hypothesis of Modigliani and the permanent income hypothesis of Friedman. The life cycle hypothesis assumes that individuals make consumption and saving decisions based on their expected lifetime income, namely, they consume less when they earn more (i.e., during active years) to have more savings to maintain their standard of living during retirement when the income is reduced (Modigliani & Brumberg, 1954). A smoothing of the consumption behavior throughout life is also suggested by the permanent

income hypothesis, which implies that during the decumulation phase, individuals are prone to enhanced spending (Friedman, 1957).

The results from this article may serve as policy recommendations. The reduction of the digital divide should represent a policy debate among the EU member states for subsequent interventions to reduce the gap, especially among vulnerable categories such as elder persons. The lack of addressing this issue might exacerbate existing divides and possibly result in further segregation of individuals in society based on their digital literacy. The digitalization of financial services will hinder vulnerable categories from investing in financial assets (i.e., elder persons). Assuring assistance regarding the use and benefits of digital services to deprived people must be considered since such persons may have integration difficulties.

Furthermore, the globalization of capital markets can potentially explain the lack of statistical significance of the real GDP/capita variable in our models, suggesting that the evolution of external markets has a greater influence on the investment behavior of older individuals, as opposed to the origin's country's economic conditions.

The main limitation identified in this study concerns the variables used in the empirical analysis, namely, the response variable is a categorical variable proxy for portfolio riskiness. Even though it is based on theoretical considerations from prior studies in the literature, it led to an exclusion of individuals from the sample that could be allocated to two risk groups at the same time. A more precise measurement of portfolio riskiness may be considered, which makes a distinction between directly holding stocks or indirectly owning stocks. Since our contribution is novel regarding the relationship between digital skills and portfolio riskiness, upon our knowledge, a drawback is related to the lack of the possibility of confronting our results with prior studies from the literature.

Digitalization may serve as a barrier for elder persons in investing in stocks since they may not have a mobile bank app/digital brokerage account or are not willing to trust such apps. Therefore, elder persons may lose significant investment opportunities and may not allocate their wealth adequately, especially in periods with high inflationary pressure, in which their wealth will diminish. Moreover, the lack of digital skills will not only refrain elder persons from participating in the stock market but will affect other aspects of their lives as well since digitalization will be implemented in other sectors and governance.

Acknowledgements: This study uses data from SHARE Wave 8 (DOI: 10.6103/SHARE.w8.800) (see Börsch-Supan et al. (2013) for methodological details). (1) The SHARE data collection has been funded by the European Commission, DG RTD through FP5 (QLK6-CT-2001-00360), FP6 (SHARE-I3: RII-CT-2006-062193, COMPARE: CIT5-CT-2005-028857, SHARE-LIFE: CIT4-CT-2006-028812), FP7 (SHARE-PREP: GA N°211909, SHARE-LEAP: GA N°227822, SHARE M4: GA N°261982, DASISH: GA N°283646) and Horizon 2020 (SHARE-DEV3: GA N°676536, SHARE-COHESION: GA N°870628, SERISS: GA N°654221, SSHOC: GA N°823782, SHARE-COVID19: GA N°101015924) and by DG Employment, Social Affairs & Inclusion through VS 2015/0195, VS 2016/0135, VS 2018/0285, VS 2019/0332, and VS 2020/0313. Additional funding from the German Ministry of Education and Research, the Max Planck Society for the Advancement of Science, the U.S. National Institute on Aging (U01_AG09740-13S2, P01_AG005842, P01_AG08291, P30_AG12815, R21_AG025169, Y1-AG-4553-01, IAG_BSR06-11, OGHA_04-064, HHSN271201300071C, RAG052527A), and from various national funding sources is gratefully acknowledged (see www.share-project.org).

Conflict of interest: Authors state no conflict of interest.

Data availability statement: The individual-level data used in this study are freely available after registration on the Survey of Health, Ageing and Retirement in Europe website. The macroeconomic datasets are available from the corresponding author upon request.

Article note: As part of the open assessment, reviews and the original submission are available as supplementary files on our website.

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Appendix

Table A1: Information criteria for the random intercept model (AIC and BIC)

Response variable: Portfolio riskiness		
Independent variables	**AIC**	**BIC**
Life satisfaction	18236.29	18257.67
Risk aversion		
Life satisfaction	18097.02	18125.52
Risk aversion		
Computer skills		
Life satisfaction	18078.68	18114.3
Risk aversion		
Computer skills		
Use of internet in the past 7 days		
Life satisfaction	18024.97	18067.71
Risk aversion		
Computer skills		
Use of internet in the past 7 days		
Years of education		
Life satisfaction	18026.26	18076.13
Risk aversion		
Computer skills		
Use of internet in the past 7 days		
Years of education		
Male or female		
Life satisfaction	18027.18	18084.17
Risk aversion		
Computer skills		
Use of internet in the past 7 days		
Years of education		
Male or female		
Age		
Life satisfaction	18025.34	18089.46
Risk aversion		
Computer skills		
Use of internet in the past 7 days		
Years of education		
Male or female		
Age		
Real GDP/capita growth rate		
Life satisfaction	18010.71	18081.95
Risk aversion		
Computer skills		
Use of internet in the past 7 days		
Years of education		
Male or female		
Age		
Real GDP/capita growth rate		
Above basic level of digital skills		
Life satisfaction	18012.27	18090.64
Risk aversion		
Computer skills		
Use of internet in the past 7 days		
Years of education		
Male or female		
Age		
Real GDP/capita growth rate		
Above basic level of digital skills		
Ordering online		
Life satisfaction	18014.26	18099.74
Risk aversion		
Computer skills		
Use of internet in the past 7 days		
Years of education		
Male or female		
Age		
Real GDP/capita growth rate		
Above basic level of digital skills		
Ordering online		
Severely materially and socially deprived		