Lisbon School of Economics & Management
Universidade de Lisboa

MASTER
FINANCE

MASTER'S FINAL WORK
DISSERTATION

FINANCIAL LITERACY, RISK TOLERANCE AND ASSET ALLOCATION IN PORTUGAL

INÊS FILIPA RICO LOPES

JUNE - 2024

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SUPERVISION:
PROFESSOR RAQUEL GASPAR

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GLOSSARY

CMVM – Comissão do Mercado de Valores Imobiliários.

EF – Efficient Frontier.

ETF – Exchange-Traded Fund.

EUT – Expected Utility Theory.

FL – Financial Literacy.

MV – Minimum Variance Portfolio.

MVT – Mean-Variance Theory.

RRA – Relative Risk Aversion.

RT – Risk Tolerance.

SR – Sharpe Ratio.

T – Tangent Portfolio.

VIF – Variance Inflation Factor.

ABSTRACT, KEYWORDS AND JEL CODES

This dissertation explores the impact of financial literacy and risk tolerance on the asset allocation choices among Portuguese individuals across various asset classes: deposits, treasury bonds, corporate bonds, stocks/equity funds, commodities, and alternative investments. Employing fractional regression models and using data from three surveys conducted by the Portuguese Securities Commission (CMVM - Comissão do Mercado de Valores Mobiliários), we find that financial literacy negatively impacts investment in deposits and treasury bonds, while positively influencing the weight allocated to corporate bonds and stocks/equity funds. Risk tolerance correlates negatively with the allocation in deposits and treasury bonds, but positively with the weight invested in stocks/equity funds and alternative investments. The average portfolios for each level of financial literacy and risk tolerance are conservative and do not seem to be efficient according to Mean-Variance Theory.

KEYWORDS: Asset Allocation; Financial Literacy; Risk Tolerance.

JEL CODES: C25; D14; G11; G25.

RESUMO, PALAVRAS-CHAVE E CÓDIGOS JEL

Esta dissertação investiga o impacto da literacia financeira e da tolerância ao risco nas escolhas de alocação de ativos financeiros entre os indivíduos Portugueses, nomeadamente em depósitos, obrigações do tesouro, obrigações corporativas, ações/fundos de ações, *commodities* e investmentos alternativos. Usando dados de três inquéritos realizados pela Comissão do Mercado de Valores Mobiliários (CMVM) e aplicando modelos de regressão fracionária, os resultados sugerem que a literacia financeira aumenta o investimento em obrigações corporativas e ações/fundos de ações, diminuindo a alocação em depósitos e obrigações do tesouro. Por sua vez, a tolerância ao risco influencia negativamente o investimento em depósitos e obrigações do tesouro e positivamente o investimento em ações/fundos de ações e investimentos alternativos. As carteiras médias para cada nível de literacia financeira e tolerância ao risco são conservadoras e não parecem ser eficientes ao nível da Teoria de Média-Variância.

PALAVRAS-CHAVE: Alocação de ativos; Literacia Financeira; Tolerância ao Risco.

CÓDIGOS JEL: C25; D14; G11; G25.

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1. INTRODUCTION

Portfolio allocation is an important research topic among finance and economics. The asset allocation decision relates to the choice of what asset classes to include in a portfolio (Bodie et al., 2018). Understanding what factors play a role in determining asset allocation choices is important for financial decision-making for both individuals and providers of financial advisory services.

One determinant of investors financial choices is financial literacy. Financial literacy is a requirement for investors to safely navigate the growing complexity of the financial markets and benefit from them. The globalisation and digitalisation of financial markets and the emergence of new instruments, accentuated by geopolitical and environmental risks and threats, such as the war in Ukraine and global warming, underscore the pressing need for financial literacy (Lusardi, 2009; Rodrigues et al.,2019; Lusardi & Messy, 2023).

There is empirical evidence that financial literacy is universally low worldwide, even in countries where financial markets are well established and developed (Lusardi & Mitchell, 2014). Portugal's average financial literacy level is below the minimum target score (at least 70 out of 100 points) but is situated at the OECD average and slightly above the overall worldwide average. Only 37% of Portuguese adults scored the minimum target score (OECD, 2023).

Moreover, an investment decision is strongly influenced by the investor's risk tolerance – or its inverse, risk aversion (Barsky et al., 1997; Adhikari & O'Leary, 2011). According to Grable & Lytton (2001), risk tolerance is assumed to be one of the main determinants of asset allocation decisions, security selection and goal-setting strategies, even though there is no single standardised assessment tool.

In this study, we examine risk tolerance and financial literacy as determinants of asset allocation choices. We rely on a set of surveys conducted by the Portuguese securities commission (CMVM – Comissão do Mercado de Valores Mobiliários) between 2021 and 2023. This research employs fractional regression analysis. Furthermore, we establish a comparative analysis within the Mean-Variance (Markowitz, 1952) setup for investors with different levels of relative risk aversion (RRA). We compare these

portfolios with the average portfolios exhibited by each financial literacy and risk tolerance level, based on the measures built for these variables.

This research contributes to the existing literature by exploring how two important factors in financial decision-making - financial literacy and risk tolerance - influence the allocation percentages of Portuguese investors across various of asset classes. The analysis focuses on deposits, treasury bonds, corporate bonds, stocks/equity funds, commodities, and alternative investments (such as cryptocurrencies). Using data from three surveys conducted from 2021 to 2023 enhances the robustness of our analysis.

The structure of this study is as follows: Section 2 provides an overview of existing literature. Section 3 describes the data and methodology used. The corresponding results and discussion are presented in Section 4. Lastly, Section 5 concludes, discussing the limitations of the analysis and providing suggestions for future research.

2. LITERATURE REVIEW

2.1 Financial Literacy

There is extensive literature on the discussion of the definition of financial literacy, however there is no universal consensus. According to OECD (2018), financial literacy is "a combination of financial awareness, knowledge, skills, attitudes and behaviours necessary to make sound financial decision and ultimately achieve financial well-being".

Research has shown that financial literacy impacts investment behaviour as well as other financial decisions (Lusardi, 2019). For instance, Lusardi & Mitchell (2014) indicate that more financially literate individuals tend to accumulate more wealth, which is supported by Bannier & Schwarz (2018). This tendency can be attributed to the fact that more literate individuals invest in more complex products, which generally offer higher returns (Lusardi, 2019), and can take advantage of the equity premium from investing in the stock market (Rooij et al., 2012). Bianchi (2018) further documents that financial literacy is positively related with portfolio returns. In accordance, Chu et al. (2017) suggest that higher financial literacy potentially leads to better financial outcomes. Conversely, low financial literacy is associated with ineffective planning and spending, expensive borrowing, and poor debt management (Lusardi, 2019).

Several studies have explored the relationship between financial literacy and market participation among the population, namely regarding investments in risky assets. Rooij et al. (2011) demonstrate that the probability of participating in the stock market increases sharply with literacy, even if only at a basic knowledge level, based on Dutch household data, while showing that there is not a strong relationship between financial literacy and owning savings accounts. Almenberg & Widmark (2011) also identified a positive correlation between financial literacy and stock ownership, relying on data from Swedish households. Further confirming these findings, Thomas & Spataro (2018), Chu et al. (2017), and Yamori & Ueyama (2022) explore this relationship based on datasets from nine European countries, China, and Japan, respectively. Conversely, Yoong (2011) documented a negative relationship between financial illiteracy and stock market participation, also aligning with the previous results. Liao et al. (2017) also report that Chinese individuals with higher financial literacy are more likely to hold risky assets. According to Grable et al. (2022), financial knowledge is positively correlated with equity holdings and negatively correlated with cash holdings.

Studies concerning financial literacy typically rely on empirical evidence and use questionnaires from surveys to construct objective financial literacy measures. In general, these surveys include a relatively standardised range of questions, including a version of "The Big Three" (Lusardi & Mitchell, 2008; 2011a; 2011b) or "The Big Five". "The Big Three" were developed to evaluate the knowledge on three core concepts: compound interest, inflation and real rates of return, and risk diversification. "The Big Five" include two additional questions that test individuals' knowledge on bond prices and mortgages and were developed for the 2009 National Financial Capability Study (Hastings et al., 2013).

Other studies analyse financial literacy also by considering the self-reported level, known as subjective financial literacy. Rooij et al. (2011) report a strong correlation between both financial literacy measures, which is even more accentuated for the advanced objective literacy index. Robb & Woodyard (2011) demonstrate that subjective literacy exerts a higher relative impact than objective literacy on financial behaviour.

This study applies a financial literacy measure that combines both measures of financial literacy into a single variable.

2.2 Risk Tolerance

Risk tolerance is a crucial determinant of numerous financial decisions (Grable & Lytton, 1999). Kogan & Wallach (1964) define risk tolerance as an individual's willingness to pursue a desirable goal, despite the uncertainty and possibility of incurring losses. Similarly, Dickason & Ferreira (2018) characterise it as being the "amount of risk or the attitude of a person that is willing to take risks when making a financial decision or investing money".

According to Corter & Chen (2006), individuals that exhibit higher tolerance tend to have high-risk portfolios. In efficient markets, higher levels of risk are expected to generate higher returns, and thus, risk tolerant individuals tend to also obtain higher returns (Yao et al., 2004). As individuals become less willing to take risks, they are less likely to participate in the stock market (Rooij et al., 2011).

Under Expected Utility Theory (EUT) (Von Neumann & Morgenstern, 1947), individuals make decisions to maximise their expected utility. Risk aversion is a crucial concept in EUT, associated with individuals' utility functions.

Although Barsky et al. (1997) established a link between a survey question and the economic concept of relative risk aversion (RRA), which is a standard way to measure risk aversion, some survey questions commonly used to measure individual's risk tolerance (or risk aversion) such as the SCF (Survey of Consumer Finance) question do not have a direct link to the economic concept of risk aversion, even if respondents are assumed to be completely rational and well-informed (Hanna et al., 2001; Yao et al., 2004). Yao et al. (2004) suggest that the SCF question constitutes an attitude variable for measuring risk tolerance, considering the possibility that respondents may be irrational and not well-informed. This study follows the same principle with the selected questions for constructing the risk tolerance measure for the different years.

Furthermore, the relationship between financial investment decisions and portfolio allocation and risk tolerance has been explored by past literature. Barsky et al. (1997) find that risk tolerance is significant and positively drives stock and bond ownership, while negatively impacting the fraction of financial assets held in treasury bills and saving accounts, which are deemed as being relatively safe assets. Hariharan et al. (2000), by testing the Capital Asset Pricing Model (CAPM) predictions, demonstrate

that risk tolerance is indeed positively related with the percentage invested in risky assets, such as stocks and bonds, while it negatively correlates with the percentage invested in risk-free securities, such as Treasury bills. Similarly, Grable & Lytton (2003) document that higher financial risk tolerance leads to an increase in the percentage ownership in equities, while leading to a decrease in the percentage in cash and fixed income products. Yook & Everett (2003) show that, for different questionnaires, the percentage of a portfolio held in stocks is positively related with risk tolerance and this relationship is significant. Gilliam et al. (2010) support these findings by showing that higher risk tolerance is associated with a greater ownership of risky assets (stocks) and decreased ownership of risk-free assets (cash). Despite using a risk aversion measure instead of risk tolerance, Shum & Faig (2006) and Grable et al. (2022) confirm these findings.

Past research has examined the demographic and individual characteristics – such as gender, age, marital status, and education – that are associated with risk tolerance (Sung & Hanna, 1996; Grable & Joo, 1999; Grable, 2000; Hallahan et al., 2004; Fisher & Yao, 2017), thus we control for those in this study.

Another important remark is that financial literacy has been proven to also impact individuals' risk tolerance (Chatterjee et al, 2017). Grable & Joo (1999) identify a positive relationship between risk tolerance and financial literacy, and similarly, Bajo et al. (2015) find that there is a negative relationship between risk aversion and financial literacy.

In this study, we use the relative weight of six asset classes within the investors' portfolios as dependent variables instead of binary variables, as most of past literature does. Thus, this study includes a broader variety of asset classes compared to previous research. While we do not specifically examine the relationship between risk tolerance and financial literacy, we acknowledge the existence of this relationship and that it should be controlled for.

3. DATA AND METHODOLOGY

3.1 Data

This study relies on a set of surveys answered by Portuguese individuals conducted by the Portuguese Securities Commission (CMVM – Comissão do Mercado de Valores Mobiliários) over the 2021-2023 period. The responses are anonymous. The surveys allow us to understand the demographic and socioeconomic profiles of the

respondents, their financial literacy level and attitude towards risk, as well as their investment preferences.

There are 1,850, 1,126 and 1,457 responses for the 2021, 2022 and 2023 surveys, respectively. However, only 1,052, 922 and 1,148 responses meet the criteria for conducting the desired research, namely by providing valid answers to the survey question asking respondents to allocate 100,000 euros across various asset classes. Responses implying short selling are and from respondents under 18 years old are not considered. Other filters are applied. One of the questions used to measure risk tolerance in 2021 (see Question 19, in Table A.1 in the Appendix) is not inherently built in a logical order. However, for the purpose of building a measure, it is assumed for instance that if an individual accepts (b), they would also accept (a); and if an individual rejects (b), then they would also reject (c) and (d). Any responses that fail to meet the conditions are considered invalid. Outlier responses that constitute errors, although not frequent in the datasets, are eliminated to ensure accuracy.

In the final datasets, respondents are predominantly male, corresponding to 55.07%, 61.24% and 59.39% of the survey participants across the years. The age group of 18 to 25 years is the most represented in the samples, with the average investor being between 32 and 36 years old. In terms of education, 39.92% (2021), 39.28% (2022) and 38.15% (2023) have advanced degrees, such as a Master's degree, MBA, or PhD, while 57.13% (2021), 54.08% (2022) and 53.42% (2023) are currently enrolled or have completed a Bachelor's degree. A considerable portion of respondents are students or student-workers, accounting for 44.50%, 43.88%, 47.47%, from 2021 to 2023; or are employed by third parties (42.79%, 46.80%, 44.25% during the same period). Most individuals report monthly household income ranging between 1,000 euros and 2,500 euros, comprising 41.24% (2021), 41.59% (2022) and 45.99% (2023) of the sample.

Concerning the perceived financial literacy level (Table I) among respondents, in 2021, 36.20% and 32.66% of valid responses belong to individuals who believe they are "Slightly knowledgeable" or "Moderately knowledgeable", respectively. Only 4.39% perceive themselves as "Very knowledgeable". In 2022, respondents are asked to evaluate their financial literacy, compared to the average Portuguese individual. Only 7.93% of respondents consider their literacy level is "Considerably below average" or "Below

average", while 24.64% believe they are "Equal to average". The remaining believe they are "Above average" (42.02%) or "Considerably above average" (14.23%). In 2023, most respondents classify themselves as "Moderately knowledgeable" (43.08%). Respondents who believe they are "Slightly knowledgeable" represent 27.60% of responses, whereas 23.97% believe they are "Knowledgeable".

Table I - Subjective (Perceived) Financial Literacy through the years

Subjective Literacy	**2021**	**2022**	**2023**
Not knowledgeable/Considerably below average	8.98%	1.05%	4.68%
Slightly Knowledgeable/Below average	36.20%	5.92%	27.60%
Moderately Knowledgeable/Equal to average	32.66%	24.64%	43.08%
Knowledgeable/Above average	17.77%	42.02%	23.97%
Very knowledgeable/Considerably above average	4.39%	14.23%	9.93%

Objective financial literacy can be deduced from questions in the surveys. These questions encompass several topics, from numeracy abilities (compounding interest) to the impact of interest rates on bond prices and the notion of diversification (see Questions 7 to 12, in Table A.1 in the Appendix). The CMVM Surveys from 2021 to 2023 mostly adhere to "The Big Five" (Lusardi and Mitchell, 2008; 2011a; 2011b; Hastings et al., 2013) questions, except for one in the 2021 Survey, for which an alternative is selected. According to Table II, the percentage of people who fail correctly answer any question is very low across the three years, while roughly 26% of the respondents in each sample answer all the questions correctly.

Table II - Breakdown of the number and percentage of correct answers

Number of Correct Answers	**2021**	**2022**	**2023**
0	28 (2.66%)	12 (1.30%)	31 (2.70%)
1	59 (5.61%)	27 (2.93%)	60 (5.23%)
2	162 (15.40%)	88 (9.54%)	137 (11.93%)
3	240 (22.81%)	199 (21.58%)	255 (22.21%)
4	286 (27.19%)	352 (38.18%)	370 (32.23%)
5	277 (26.33%)	244 (26.46%)	295 (25.70%)
Average Number of Correct Answers	3.45	3.72	3.53

Table III provides a breakdown of the percentage of correct and incorrect answers per question. The number respondents who provide no answer is minimal; therefore, they are grouped with "Do not know". The question inquiring about the effect of interest rates

on bond prices (Bond) exhibits the lowest percentage of correct answers, accompanied by a relatively high percentage of respondents who "Do not know" or do not respond. This suggests that fixed income products such as bonds may be less familiar to the general population. Conversely, the question inquiring about the effect of inflation on the purchasing power has the highest percentage of correct answers. The 2021 Survey question about structured products (PRIIPs) exhibits the highest percentage of respondents who "Do not know" or do not respond, indicating that most people may not be aware of the existence and complexity of these products. Regarding the diversification question, a considerable percentage of the sample recognises the effect of diversification on minimising risk. The average number of correct responses stands at 3.45 (2021), 3.72 (2022) and 3.53 (2023) questions.

Table III - Breakdown of the percentage of correct/incorrect answers per question

	Questions/Answers	Compound Interest	Inflation	Bond	Mortgage/ PRIIPS	Diversification
2021	Correct	69.87%	86.31%	41.35%	64.83%	82.89%
	Incorrect	28.04%	7.70%	39.45%	3.14%	16.92%
	Do not know/No response	2.09%	5.99%	19.20%	32.03%	0.19%
2022	Correct	72.45%	93.06%	37.42%	82.65%	86.23%
	Incorrect	25.60%	3.69%	43.60%	12.26%	2.82%
	Do not know/No response	1.95%	3.25%	18.98%	5.10%	10.95%
2023	Correct	66.81%	91.11%	38.94%	76.83%	79.44%
	Incorrect	28.57%	2.70%	38.59%	13.68%	4.01%
	Do not know/No response	4.62%	6.18%	22.47%	9.49%	16.55%

Table IV shows that women exhibit lower rates of correct responses to each question compared to men. This aligns with existing literature that states that women tend to be less financially literate (Chen & Volpe, 2002; Lusardi & Mitchell, 2008, 2011b, 2014). Moreover, a greater percentage of women also tend to acknowledge not knowing the answer to a question, as also shown by Lusardi & Mitchell (2014).

Table IV- Breakdown of the percentage of correct /incorrect answers by gender

		2021		2022		2023	
		Female	**Male**	**Female**	**Male**	**Female**	**Male**
Compound Interest	Correct	56.72%	80.56%	63.46%	78.25%	54.78%	74.89%
	Incorrect	36.46%	18.75%	33.99%	20.32%	38.91%	21.71%
	Do not know/No response	6.82%	0.69%	2.55%	1.43%	6.30%	3.40%
Inflation	Correct	76.55%	94.10%	87.25%	96.79%	85.22%	94.98%
	Incorrect	12.58%	3.82%	6.23%	2.14%	4.35%	1.62%
	Do not know/No response	10.87%	2.08%	6.52%	1.07%	27.83%	18.91%
Diversification	Correct	74.63%	89.58%	77.90%	91.98%	69.13%	86.41%
	Incorrect	11.09%	4.86%	2.83%	2.50%	5.87%	2.81%
	Do not know/No response	14.29%	5.56%	19.26%	5.53%	25.00%	10.78%
Bond	Correct	27.51%	52.78%	28.05%	43.49%	25.87%	47.86%
	Incorrect	47.76%	32.47%	45.89%	42.07%	46.30%	33.23%
	Do not know/No response	24.73%	14.76%	26.06%	14.44%	27.83%	18.91%
Mortgages/ PRIIPs (2021)	Correct	58.21%	69.97%	83.29%	82.35%	70.43%	81.09%
	Incorrect	2.13%	3.99%	11.33%	13.01%	18.04%	10.78%
	Do not know/No response	39.66%	26.04%	5.38%	4.63%	11.52%	8.12%

Furthermore, this study also examines risk tolerance, assuming it to be the inverse of risk aversion, as Grable et al. (2022). It is possible to analyse the perception respondents have of their own attitude towards risk (Table V). The 2023 Survey does not feature a question inquiring about the respondents' risk perception. The 2022 Survey does not allow for risk neutrality, contrary to the 2021 Survey. Both the 2021 and 2022 samples demonstrate a predominance of investors who perceive themselves as risk averse (or extreme risk averse).

Table V - Perceived Risk Aversion

Perceived Risk Aversion	**2021**	**2022**
Extreme Risk Lover	0.95%	3.28%
Risk Lover	16.73%	29.48%
Risk Neutral	21.96%	-
Risk Averse	47.34%	51.42%
Extreme Risk Averse	13.02%	15.83%

It becomes evident that women are more risk averse than men (Table VI), as expected from past literature (Jianakoplos & Bernasek, 1998; Grable, 2000; Grable et al., 2004; Hallahan et al., 2004; Hanna & Lindamood, 2004; Gibson et al., 2013). This is

exhibited by a lower percentage of women who are risk lovers or extreme risk lovers, alongside a higher percentage of risk averse or extreme averse women compared to men.

Table VI - Perceived Risk Aversion by Gender

Perceived Risk Aversion	2021		2022	
	Female	Male	Female	Male
Extreme Risk Lover	0.00%	1.74%	0.57%	5.03%
Risk Lover	7.68%	24.13%	19.37%	35.91%
Risk Neutral	17.48%	25.35%	-	-
Risk Averse	56.29%	40.10%	56.13%	48.47%
Extreme Risk Averse	18.55%	8.68%	23.93%	10.59%

3.2 Methodology

The purpose of this research is to explore the influence of risk tolerance and financial literacy on investment allocation choices between different asset classes, while controlling for other factors such as demographic and socioeconomic aspects. To this end, the variables are defined based on the survey questions. However, due to inconsistencies in the questions through the years, it was necessary to uniformise them to ensure comparability in the yearly results, when possible.

The dependent variables of this study are the percentage held in each asset class, ranging from 0 to 1. These variables are derived from a question that requires the respondents to hypothetically allocate 100,000 euros among different asset classes. Responses that do not sum up to 100,000 euros are deemed as invalid, respecting the baseline construction of the question. Given the inconsistencies in the asset classes provided across the three surveys, when defining the dependent variables, the denominator is not 100,000 euros, but rather the sum of the asset classes is common in the three surveys. The final group of asset classes is Deposits, Treasury Bonds (T-Bonds), Corporate Bonds (C. Bonds), Stocks and equity funds (Stocks), Commodities (Comm.), and Alternative investments (Altern.), which namely include cryptocurrencies and crowdfunding. It however should be noted that the 2021 Survey does not differentiate between treasury and corporate bonds within the bond class. To address this, an assumption is made based on the 2022 average proportion (see Table A.2 in the Appendix) of each of the bond classes. Approximately one third of the 2022 bond investments are in corporate bonds, while the remaining is allocated to treasury bonds.

To build the financial literacy variable, both subjective and objective financial literacy measures are considered. Subjective financial literacy corresponds to individuals' perception of their financial expertise. This measure is directly derived from a question within the survey (see Questions 13 and 14 in Table A.1 in Appendix), coded from to 1 to 5. Objective financial literacy is derived from the answers given to five multiple-choice questions (see Questions 7 to 12, in Table A.1 in the Appendix), which are coded as 1 if the answered correctly or as 0 if answered incorrectly or left unanswered. The scores from each question are summed resulting in a measure ranging from 1 to 5. A score of 1 indicates that the respondent did not provide any correct answers, while a score of 5 indicates that all questions were answered correctly.

The financial literacy variable results from summing both subjective and objective scores (*SumScoresFL*). The combined score is mapped to a scale as seen in Equation (1).

$$financial\ literacy = \begin{cases} 1, \text{if } SumScoresFL = 2 \vee SumScoresFL = 3 \\ 2, \text{if } SumScoresFL = 4 \vee SumScoresFL = 5 \\ 3, \quad \text{if } SumScoresFL = 6 \\ 4, \text{if } SumScoresFL = 7 \vee SumScoresFL = 8 \\ 5, \text{if } SumScoresFL = 9 \vee SumScoresFL = 10 \end{cases} \quad (1)$$

For 2021 and 2022, risk tolerance is assessed by considering both the respondents' perception of their attitude towards risk and a supplementary risk tolerance measure retrieved from questions within the surveys. Due to inconsistencies in the surveys over the years, the latter is deduced from a different question in each of the surveys. Details are available in Table A.1 in the Appendix. The self-reported risk tolerance is coded as in Questions 16 and 18 in Table A.1 in the Appendix. The chosen 2021 supplementary measure question (see Question 19, in Table A.1 in the Appendix) is not inherently built in a logical order. However, a transitive relationship (Equation 2) and its contrapositive are assumed for response hierarchy.

$$accept\ (d) \Rightarrow accept\ (c) \Rightarrow accept\ (b) \Rightarrow accept(a) \quad (2)$$

This assumption allows to define five levels of risk tolerance: 1 if (a), (b), (c), and (d) are rejected; 2 if (a) is accepted but (b), (c), and (d) are rejected; 3 if (a) and (b) are accepted but (c) and (d) are rejected; 4 if (a), (b), and (c) are accepted but (d) is rejected; 5 if (a), (b), (c), and (d) are all accepted.

The 2022 supplementary risk tolerance measure (see Question 17, in Table A.1 in the Appendix) resembles a widely used tool for measuring risk tolerance, which is the single-question instrument from the SCF (Survey of Consumer Finances). A score is established as shown in Table A.1 in the Appendix.

Ultimately, for 2021 and 2022, the risk tolerance variable is built by summing the scores from the two questions ($SumScoresRT$), which is then mapped as in Equation (3).

$$risk\ tolerance = \begin{cases} 1, \text{if } SumScoresRT = 2 \vee SumScoresRT = 3 \\ 2, \text{if } SumScoresRT = 4 \vee SumScoresRT = 5 \\ 3, \quad \text{if } SumScoresRT = 6 \\ 4, \text{if } SumScoresRT = 7 \vee SumScoresRT = 8 \\ 5, \text{if } SumScoresRT = 9 \vee SumScoresRT = 10 \end{cases} \quad (3)$$

It is important to note that the 2023 risk tolerance measure differs from the 2021 and 2022 measures. It relies solely on a single question (see Question 15, in Table A.1 in the Appendix), given that the 2023 survey does not inquire about perceived risk aversion. Respondents were asked to consider a financial product that provides an equal chance of losing 50 euros or gaining a certain amount and to specify the minimum gain needed to make such investment. Scores are assigned as follows: 1 for responses equal to or higher than 125 euros; 2 for responses between 50 and 125 euros; 3 for responses equal to 50 euros; 4 for responses equal or higher than 20 euros and below 50 euros; and 5 for responses below 20 euros. A higher score indicates a higher level of risk tolerance.

In terms of control variables, the variable $male$ is binary variable that takes the value 1 if the respondent is male, and 0 otherwise. Age is a numerical variable that can take any value higher than 18 years. The education level (variable $education$) can take six different values, ranging from 1 to 6, as coded in Question 3 in Table A.1 in the Appendix. The $monthly\_income$ variable is categorised as follows: 1 for monthly household incomes of 500 euros or less, 2 for incomes between 501 euros and 1,000 euros, 3 for incomes between 1,001 euros and 2,500 euros, 4 for incomes between 2,501 euros and 5,000 euros, and 5 for incomes exceeding 5,000 euros. In addition, four binary variables were added to account for the respondents' occupation for each of the following labour status: self-employed, employee (to third parties), unemployed, or retired. To avoid the dummy variable trap, the occupation binary variable representing students/working-students is omitted.

The descriptive statistics of the defined variables are available in Table A.2 in the Appendix. Missing values in some of these variables are handled by imputation using the mode.

3.2.1 Regression models

To investigate the relationship between the dependent variables and independent and control variables, the model in Equation (4) is built for each asset class i and for each year.

$$\begin{aligned} w_i = \beta_0 + \beta_1 financial\_literacy + \beta_2 risk\_tolerance + \beta_3 male + \beta_4 age \\ + \beta_5 education + \beta_6 monthly\_income + \beta_7 employee \\ + \beta_8 self employed + \beta_9 retired + \beta_{10} unemployed, \end{aligned} \quad (4)$$

for $i = \{Deposits, T-Bonds, C.Bonds, Stocks, Comm., Altern.\}$

The dependent variables, denoting the weight in each asset class, inherently range from 0 to 1 and represent a proportion. Gilliam (2010) applies the Tobit regression to a fractional dependent variable referring to the percentage allocation in stocks. However, Baum (2008) argues that the Tobit Model is inappropriate for dealing with proportions, because the observed values are naturally restricted to the [0,1] interval, and thus do not constitute a case of censored data. Papke & Wooldridge (1996) contend that the existence of fractional dependent variables is not compatible with ordinary linear regression and propose employing a nonlinear link function, such as the probit or logistic functions, to ensure that the predicted values remain bounded within the range of 0 to 1. The parameters in fractional regressions are estimated using Quasi-Maximum Likelihood estimators. In this study, a fractional response model is employed to each dependent variable.

Testing for multicollinearity, the correlation matrices (Tables A.3 to A.5 in the Appendix) are analysed. Generally, if any pairwise correlation coefficient is greater than 0.8, there is reason for concern. For binary variables, tetrachoric correlation is computed.

The Variance Inflation Factor (VIF) is also used to evaluate the presence of multicollinearity. As a rule of thumb, a VIF higher than 10 suggests high multicollinearity. Table VII shows no evident signs of multicollinearity, as the VIF ranges between 1.41 to 1.52, well below the threshold of 10.

Table VII - Variance Inflation Factor (VIF)

Variable	2021		2022		2023	
	VIF	1/VIF	VIF	1/VIF	VIF	1/VIF
financial_literacy	1.25	0.80	1.29	0.78	1.24	0.81
risk_tolerance	1.16	0.86	1.21	0.83	1.04	0.96
male	1.23	0.81	1.16	0.86	1.15	0.87
age	2.33	0.43	2.10	0.48	2.29	0.44
monthly_income	1.60	0.63	1.31	0.76	1.17	0.85
education	1.76	0.57	1.44	0.69	1.44	0.69
selfemployed	1.33	0.75	1.32	0.76	1.32	0.76
employee	2.24	0.45	1.91	0.52	2.19	0.46
retired	1.16	0.86	1.27	0.79	1.23	0.81
unemployed	1.12	0.89	1.11	0.90	1.06	0.94
Mean VIF	1.52		1.41		1.41	

To enhance robustness, the additional models in Equations (5) and (6) are estimated. These models regress the dependent variable on risk tolerance and financial literacy separately, while accounting for the control variables.

$$w_i = \alpha_0 + \alpha_1 financial\_literacy + \alpha_2 male + \alpha_3 age + \alpha_4 education + \alpha_5 monthly\_income + \alpha_6 employee + \alpha_7 selfemployed + \alpha_8 retired + \alpha_9 unemployed \quad (5)$$

$$w_i = \gamma_0 + \gamma_1 risk\_tolerance + \gamma_2 male + \gamma_3 age + \gamma_4 education + \gamma_5 monthly\_income + \gamma_6 employee + \gamma_7 selfemployed + \gamma_8 retired + \gamma_9 unemployed \quad (6)$$

for $i = \{Deposits, T-Bonds, C.Bonds, Stocks, Comm., Altern.\}$

3.2.2 Mean-Variance Analysis

This study endeavours to go beyond the models established in the previous section by constructing portfolios tailored to different risk tolerance levels, under the lenses of Modern Portfolio Theory (Markowitz, 1952) and Expected-Utility Theory (Von Neumann & Morgenstern, 1947). The purpose is to compare these results to the average asset allocation observed for each level of risk tolerance and financial literacy level for the deduced variables. A 10-year investment horizon is assumed, and short-selling is not allowed.

To carry out the Mean-Variance Theory (MVT) application, data on different Exchange-Traded Funds (ETFs) is collected, aiming to capture each of the asset class under analysis in the previous section. The daily prices for the ETFs described in Table VIII are extracted from 1st January 2011 to 31st December 2022. For each year, daily prices dating 10 years are used.

Table VIII - Description of the ETFs used as benchmark for the asset classes

ETFs	
iShares Core € Govt Bond UCITS ETF EUR	Fixed Income (Treasury)
iShares Core € Corp Bond UCITS ETF	Fixed Income (Corporate)
iShares STOXX Europe 600 UCITS ETF (DE)	Equity
UBS ETF Bloomberg Commodity Index SF UCITS ETF	Commodities
Grayscale Bitcoin Trust	Alternative Investments

Additionally, a risk-free asset (R_f) is considered for each year (Table IX), using a 10-year German government bond yield as a proxy, to represent the deposit rate.

Table IX - Risk free asset by year

2021	-0.56%	on 30/12/2020
2022	-0.21%	on 30/12/2021
2023	2.51%	on 30/12/2022

Source: *Bundesbank*

Given the set of ETFs, Mean-Variance Theory (MVT) allows to find all efficient combinations of these assets, i.e., all the portfolios with the highest expected return, for each level of risk.

Assuming that the individual returns are given by R_i $(i = 1,2, \dots, n)$, the weight in each asset i in the portfolio is given by x_i $(i = 1,2, \dots, n)$ and the σ_{ij} corresponds to the covariance between the returns of assets i and j $(i, j = 1,2, \dots, n, \ i \neq j)$, the vector notation can be established as follows:

$$\overline{\boldsymbol{R}} = \begin{bmatrix} R_1 \\ R_2 \\ \vdots \\ R_n \end{bmatrix}, \boldsymbol{X} = \begin{bmatrix} x_1 \\ x_2 \\ \vdots \\ x_n \end{bmatrix}, \boldsymbol{V} = \begin{bmatrix} \sigma_1^2 & \sigma_{12} & \cdots & \sigma_{1n} \\ \sigma_{21} & \sigma_2^2 & \cdots & \sigma_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \sigma_{n1} & \sigma_{n2} & \cdots & \sigma_n^2 \end{bmatrix} \text{ and } \boldsymbol{1} = \begin{bmatrix} 1 \\ 1 \\ \vdots \\ 1 \end{bmatrix} \tag{7}$$

The expected return and risk of a portfolio with n assets are respectively:

$$\bar{R}_p = \boldsymbol{X'}\bar{\boldsymbol{R}} \tag{8}$$

$$\sigma_P = \sqrt{\boldsymbol{X'VX}} \tag{9}$$

It should be noted that the portfolio must verify:

$$\boldsymbol{X'1} = 1 \tag{10}$$

The MVT efficient portfolios computation relies on numerical solutions, since a no short-selling restriction was imposed. Some relevant portfolios ought to be computed, including the Tangent (T) portfolio and the Minimum Variance (MV) portfolio. The tangent portfolio is the one that maximises the Sharpe Ratio (SR):

$$\begin{aligned} \max_X \quad & \frac{\bar{R}_p - R_f}{\sigma_P} \\ \text{s.t } & X'\mathbf{1} = 1 \\ & x_i \geq 0, \forall i \end{aligned}$$

On the other hand, the minimum variance portfolio is the one that exhibits the lowest variance (lowest risk) within the efficient frontier (EF).

$$\begin{aligned} \min_X \quad & X'VX \\ \text{s.t } & X'\mathbf{1} = 1 \\ & x_i \geq 0, \forall i \end{aligned}$$

Under uncertainty, Expected-Utility Theory (EUT) allows to define the optimal portfolios situated along the efficient frontier, provided that investors adhere to rationality axioms.

The risk-tolerance function (RTF) corresponds to the expected utility of terminal wealth. For each RRA level at initial wealth, the second-order Taylor approximation of the risk-tolerance function is given by Equation (11).

$$f(\sigma_P, \bar{R}_p) \approx \bar{R}_p - \frac{1}{2} RRA(\bar{R}_p^2 + \sigma_P^2) \tag{11}$$

The maximisation problem that solves for the optimal portfolios within the efficient frontier, for each RRA = $\{-1, 0, 1, 2, 3, 4, 5, 6\}$, as in Gaspar & Oliveira (2024), is formulated as follows:

$$\max_{X} \quad \bar{R}_p - \frac{1}{2} RRA\left(\bar{R}_p^2 + \sigma_P^2\right)$$
$$\text{s.t} \quad X'\mathbf{1} = 1$$
$$x_i \geq 0, \forall i$$

4. RESULTS

This chapter presents and examines the results from the regression analysis, along with the findings from the Mean-Variance setup analysis conducted.

4.1 Regression analysis

For each weight variable, three models are built to analyse the impact of risk tolerance and financial literacy. Model 1 regresses the dependent variable on financial literacy (Equation 5), Model 2 on risk tolerance (Equation 6), and Model 3 incorporates both variables (Equation 4), controlling for the demographic and socioeconomic variables. Model 3 serves as the primary model in this study.

The regression outputs are presented by riskiness of the asset class underlying the dependent variable.

Table X summarises the results for the models across the years for the regressions on the weight allocated in deposits ($w\_deposits$). Financial literacy is statistically significant at a 1% significance level for all models and has a negative relationship with the dependent variable. Considering the tendency among the Portuguese population to heavily invest in deposits (European Central Bank, 2016), this finding suggests that as people become more financially literate, they tend to allocate a smaller percentage of their wealth to deposits. This is likely due to an increased awareness of alternative investment opportunities, resulting from higher financial knowledge.

Risk tolerance shows statistical significance at a 1% significance level in 2021 and 2022 and registers a negative coefficient. Deposits are typically perceived as safe investments and it is common practice to hold funds in deposit accounts in banks. The negative relationship between risk tolerance and the percentage invested in deposits aligns with the perception that deposits are low risk investments. As investors become more risk tolerant, they invest less as deposits, potentially opting for riskier alternatives. These findings align with Gilliam et al. (2010) if we assume that deposits are mostly risk-free. However, the 2023 models suggest a positive relationship, contrary to previous

years. This may be attributed to limitations within the 2023 dataset, regarding the construction of the risk tolerance measure and the survey question selected for it. The 2021 and 2022 results are presumed to be less subject to biases.

Across the years, being a male is statistically significant with negative coefficients. Given the low-risk nature of deposits, it is unsurprising since women tend to be less risk tolerant (Jianakoplos & Bernasek, 1998; Grable, 2000; Grable et al., 2004; Hallahan et al., 2004; Hanna & Lindamood, 2004; Gibson et al., 2013).

The results regarding the weight invested in treasury bonds (w_tbonds) as the dependent variable vary across the years (Table XI). Financial literacy is statistically significant at a 1% significance level for 2021 and 2023, but the direction of this relationship is unclear as it is not consistent across the years.

Risk tolerance exhibits statistical significance at the 1% or 5% significance level for the three years, with a negative coefficient. Treasury bonds are also perceived as low risk by common people, similarly to deposits. It also seems to be in accordance with Barsky et al. (1997) and Grable & Lytton (2003).

The regression results on the allocation on corporate bonds (w_cbonds) are depicted in Table XII. Financial literacy emerges as statistically significant at 1% significance level through the years. Financial literacy consistently exerts a positive impact on the weight invested in corporate bonds. As financial literacy increases, individuals tend to become more acquainted with financial instruments such as corporate bonds potentially increasing their propensity to invest in them. This is supported by the statistics regarding responses to the Bond question (Table III), in the previous chapter.

On the other hand, risk tolerance is negatively associated with the weight of corporate bonds in the portfolio, for the main model in 2021 and 2022, but it is only significant for 2021. In 2022, the risk tolerance coefficient is negative for Model 3 but not for Model 2. It seems to suggest that there is indeed a relationship between risk tolerance and financial literacy, in accordance with Chatterjee et al. (2017). Once again, we consider the 2021 and 2022 findings regarding risk tolerance to be less biased.

Table X - Fractional Regressions for $w\_deposits$ for 2021-2023

	2021			2022			2023		
	Model 1	**Model 2**	**Model 3**	**Model 1**	**Model 2**	**Model 3**	**Model 1**	**Model 2**	**Model 3**
financial_literacy	-0.274***		-0.212***	-0.196***		-0.116**	-0.262***		-0.258***
	(0.0412)		(0.0416)	(0.0560)		(0.0539)	(0.0470)		(0.0470)
male	-0.336***	-0.343***	-0.196**	-0.333***	-0.235**	-0.189**	-0.374***	-0.553***	-0.375***
	(0.0906)	(0.0871)	(0.0922)	(0.0948)	(0.0918)	(0.0952)	(0.101)	(0.0956)	(0.101)
age	0.0222***	0.0185***	0.0186***	0.0132***	0.00545	0.00466	0.00473	0.00498	0.00380
	(0.00466)	(0.00462)	(0.00467)	(0.00413)	(0.00422)	(0.00426)	(0.00473)	(0.00473)	(0.00475)
monthly_income	0.0280	0.0197	0.0248	0.0639	0.0489	0.0724	0.104*	0.0463	0.107*
	(0.0496)	(0.0493)	(0.0487)	(0.0559)	(0.0550)	(0.0558)	(0.0573)	(0.0565)	(0.0573)
education	0.0986*	0.0337	0.0849	0.0431	-0.0275	0.000561	0.0519	0.00807	0.0528
	(0.0565)	(0.0539)	(0.0553)	(0.0559)	(0.0597)	(0.0586)	(0.0587)	(0.0577)	(0.0588)
selfemployed	-0.230	-0.135	-0.163	-0.546**	-0.391	-0.379	-0.0767	-0.128	-0.0606
	(0.216)	(0.214)	(0.215)	(0.239)	(0.245)	(0.244)	(0.224)	(0.224)	(0.223)
employee	-0.218*	-0.149	-0.195	-0.151	-0.0719	-0.0624	-0.283**	-0.321**	-0.290**
	(0.126)	(0.127)	(0.128)	(0.114)	(0.116)	(0.117)	(0.130)	(0.131)	(0.130)
retired	0.0556	0.157	0.0866	-0.263	-0.155	-0.136	0.530	0.467	0.536
	(0.421)	(0.425)	(0.378)	(0.379)	(0.358)	(0.368)	(0.506)	(0.487)	(0.502)
unemployed	-0.203	-0.127	-0.129	-0.258	-0.164	-0.179	0.514	0.582	0.539
	(0.247)	(0.255)	(0.260)	(0.388)	(0.394)	(0.391)	(0.476)	(0.460)	(0.473)
risk_tolerance		-0.394***	-0.351***		-0.371***	-0.354***		0.0938*	0.0788
		(0.0440)	(0.0445)		(0.0443)	(0.0442)		(0.0488)	(0.0489)
constant	-0.562**	0.0298	0.269	-0.891***	-0.151	0.0398	-0.752**	-1.317***	-0.912***
	(0.253)	(0.271)	(0.277)	(0.337)	(0.334)	(0.356)	(0.312)	(0.322)	(0.330)
Pseudo R^2	0.0404	0.0512	0.0588	0.0179	0.0384	0.0399	0.0261	0.0166	0.0271

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table XI - Fractional Regressions for w_tbonds for 2021-2023

	2021			2022			2023		
	Model 1	**Model 2**	**Model 3**	**Model 1**	**Model 2**	**Model 3**	**Model 1**	**Model 2**	**Model 3**
financial_literacy	0.268***		0.302***	-0.124**		-0.0385	-0.112***		-0.119***
	(0.0416)		(0.0414)	(0.0593)		(0.0599)	(0.0429)		(0.0432)
male	0.0701	0.346***	0.144	-0.0284	0.112	0.127	-0.123	-0.206**	-0.123
	(0.0926)	(0.0923)	(0.0945)	(0.105)	(0.102)	(0.106)	(0.0887)	(0.0841)	(0.0886)
age	0.00527	0.00285	0.00336	0.0388***	0.0302***	0.0300***	0.0220***	0.0237***	0.0232***
	(0.00453)	(0.00476)	(0.00463)	(0.00513)	(0.00500)	(0.00502)	(0.00416)	(0.00414)	(0.00416)
monthly_income	-0.0570	-0.0499	-0.0567	-0.0461	-0.0477	-0.0398	-0.0208	-0.0514	-0.0230
	(0.0532)	(0.0550)	(0.0524)	(0.0632)	(0.0617)	(0.0632)	(0.0520)	(0.0498)	(0.0519)
education	0.0646	0.131**	0.0584	0.210***	0.161***	0.170***	0.143***	0.122**	0.142***
	(0.0570)	(0.0560)	(0.0568)	(0.0602)	(0.0593)	(0.0616)	(0.0514)	(0.0508)	(0.0512)
selfemployed	0.171	0.180	0.230	-0.513**	-0.360	-0.356	-0.162	-0.211	-0.180
	(0.219)	(0.225)	(0.217)	(0.217)	(0.226)	(0.224)	(0.190)	(0.191)	(0.190)
employee	0.0863	0.0489	0.107	-0.286**	-0.224*	-0.221*	0.237**	0.226*	0.243**
	(0.126)	(0.126)	(0.125)	(0.133)	(0.132)	(0.132)	(0.116)	(0.117)	(0.116)
retired	0.222	0.169	0.236	-0.562	-0.449	-0.445	0.0168	-0.0160	0.0108
	(0.556)	(0.591)	(0.591)	(0.452)	(0.442)	(0.443)	(0.462)	(0.468)	(0.464)
unemployed	-0.183	-0.159	-0.135	0.171	0.260	0.254	-0.164	-0.174	-0.194
	(0.242)	(0.249)	(0.249)	(0.380)	(0.344)	(0.345)	(0.476)	(0.481)	(0.477)
risk_tolerance		-0.0945**	-0.165***		-0.389***	-0.384***		-0.0920**	-0.0997**
		(0.0440)	(0.0447)		(0.0437)	(0.0446)		(0.0428)	(0.0427)
constant	-3.485***	-2.743***	-3.125***	-3.195***	-2.283***	-2.220***	-1.856***	-1.847***	-1.658***
	(0.255)	(0.277)	(0.270)	(0.339)	(0.343)	(0.352)	(0.262)	(0.268)	(0.278)
Pseudo R^2	0.0173	0.008	0.0207	0.0488	0.0714	0.0716	0.0381	0.0373	0.0396

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table XII - Fractional Regressions for w_cbonds for 2021-2023

	2021			2022			2023		
	Model 1	**Model 2**	**Model 3**	**Model 1**	**Model 2**	**Model 3**	**Model 1**	**Model 2**	**Model 3**
financial_literacy	0.252***		0.284***	0.207***		0.211***	0.301***		0.301***
	(0.0392)		(0.0389)	(0.0681)		(0.0690)	(0.0599)		(0.0599)
male	0.0667	0.326***	0.136	0.0684	0.161	0.0767	-0.140	0.0587	-0.140
	(0.0872)	(0.0870)	(0.0887)	(0.109)	(0.110)	(0.113)	(0.126)	(0.119)	(0.126)
age	0.00494	0.00268	0.00316	0.00619	0.00419	0.00575	0.0110**	0.00961*	0.0110**
	(0.00424)	(0.00447)	(0.00433)	(0.00526)	(0.00530)	(0.00534)	(0.00541)	(0.00541)	(0.00538)
monthly_income	-0.0541	-0.0472	-0.0535	-0.0127	0.0253	-0.0123	-0.0732	-0.00463	-0.0732
	(0.0500)	(0.0520)	(0.0493)	(0.0670)	(0.0652)	(0.0670)	(0.0752)	(0.0750)	(0.0753)
education	0.0609	0.124**	0.0549	-0.0435	0.00122	-0.0456	-0.0473	0.00791	-0.0473
	(0.0538)	(0.0529)	(0.0536)	(0.0641)	(0.0624)	(0.0647)	(0.0699)	(0.0699)	(0.0699)
selfemployed	0.161	0.170	0.217	0.217	0.250	0.225	-0.345	-0.265	-0.345
	(0.204)	(0.210)	(0.202)	(0.276)	(0.275)	(0.275)	(0.253)	(0.251)	(0.253)
employee	0.0817	0.0466	0.101	-0.0920	-0.0638	-0.0875	-0.338**	-0.302*	-0.338**
	(0.118)	(0.118)	(0.117)	(0.136)	(0.136)	(0.136)	(0.162)	(0.164)	(0.162)
retired	0.205	0.158	0.216	0.262	0.309	0.269	-0.650	-0.609	-0.650
	(0.512)	(0.547)	(0.543)	(0.325)	(0.329)	(0.327)	(0.516)	(0.516)	(0.516)
unemployed	-0.171	-0.149	-0.126	-0.476	-0.492	-0.470	-0.0904	-0.133	-0.0903
	(0.229)	(0.236)	(0.236)	(0.438)	(0.431)	(0.440)	(0.394)	(0.393)	(0.393)
risk_tolerance		-0.0889**	-0.155***		0.00989	-0.0169		-0.0168	0.000621
		(0.0414)	(0.0418)		(0.0454)	(0.0469)		(0.0563)	(0.0571)
constant	-4.159***	-3.461***	-3.821***	-3.094***	-2.638***	-3.048***	-3.287***	-2.764***	-3.288***
	(0.241)	(0.262)	(0.254)	(0.347)	(0.357)	(0.379)	(0.388)	(0.414)	(0.410)
Pseudo R^2	0.0133	0.0062	0.0159	0.0069	0.0034	0.0069	0.0121	0.0017	0.0121

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table XIII displays the regressions results for the weight invested in stocks and/or equity funds (w_stocks). Financial literacy is statistically significant at 1% level across all years, positively impacting the percentage invested in stocks and/or equity funds. Given their complexity, it is expected that more financial literate individuals tend to invest higher proportions in them. This result is quite robust, confirmed across the three years. These findings align with Almenberg & Widmark (2011), Rooij et al. (2011), and Yoong (2011), despite their use of binary dependent variables for stock ownership in these past studies.

Risk tolerance exhibits statistical significance at a 1% level, for 2021 and 2022, further indicating a potential issue in the construction of the 2023 measure. As individuals become more risk tolerant, they demonstrate a greater inclination towards riskier investments such as stocks and/or equity fund investments. These results are consistent with Gilliam et al. (2010), as well as Grable & Lytton (2003) and Barsky et al. (1997).

Table XIV presents the results of regressions analysing investment weight on commodities (w_comm). Risk tolerance is not significant in any of the models, while financial literacy is significant only for 2022, although it exhibits a negative coefficient across the three years. Neither variable shows robust statistical significance.

Finally, the regression results for alternative investments (such as cryptocurrencies) (w_altern) are displayed on Table XV. Financial literacy exhibits statistical significance only for 2021. Although not statistically significant in 2022 and 2023, its coefficient is consistently negative across the years. The lack of statistical significance in 2022 and 2023 aligns with Arias-Oliva et al. (2019), who found no significant link between financial literacy and cryptocurrency investment. However, studies have yielded mixed results. Past research report that subjective financial literacy (Panos et al., 2020; Zhao & Zhang, 2021; Kim et al., 2023) has positive relationship with cryptocurrency investment while objective financial literacy has a negative relationship (Kim et al.,2023).

Risk tolerance is statistically significant only for the 2021 and 2022. The observed positive relationship between risk tolerance and alternative investments, such as cryptocurrencies, is supported by prior research (Stix, 2021; Hayashi & Routh, 2024). These findings suggest that individuals recognise cryptocurrencies as very risky, potentially due to their highly volatile nature.

Table XIII - Fractional Regressions for w_stocks for 2021-2023

	2021			2022			2023		
	Model 1	**Model 2**	**Model 3**	**Model 1**	**Model 2**	**Model 3**	**Model 1**	**Model 2**	**Model 3**
financial_literacy	0.198***		0.144***	0.322***		0.204***	0.332***		0.334***
	(0.0351)		(0.0352)	(0.0564)		(0.0547)	(0.0428)		(0.0430)
male	0.269***	0.227***	0.123	0.337***	0.203**	0.111	0.442***	0.657***	0.443***
	(0.0773)	(0.0768)	(0.0806)	(0.0862)	(0.0855)	(0.0849)	(0.0864)	(0.0837)	(0.0864)
age	-0.0264***	-0.0231***	-0.0230***	-0.0393***	-0.0300***	-0.0281***	-0.0251***	-0.0269***	-0.0255***
	(0.00437)	(0.00434)	(0.00434)	(0.00495)	(0.00467)	(0.00464)	(0.00447)	(0.00456)	(0.00447)
monthly_income	0.0474	0.0580	0.0563	0.0307	0.0552	0.0201	0.0392	0.116**	0.0397
	(0.0452)	(0.0459)	(0.0453)	(0.0555)	(0.0500)	(0.0505)	(0.0522)	(0.0521)	(0.0522)
education	-0.0624	-0.0176	-0.0540	-0.0864*	0.0238	-0.0217	-0.0994**	-0.0318	-0.100**
	(0.0505)	(0.0506)	(0.0510)	(0.0494)	(0.0477)	(0.0482)	(0.0491)	(0.0506)	(0.0491)
selfemployed	0.103	-0.00112	0.00170	0.654***	0.435*	0.416*	0.0276	0.125	0.0333
	(0.189)	(0.182)	(0.181)	(0.236)	(0.230)	(0.225)	(0.197)	(0.199)	(0.197)
employee	0.0864	0.0224	0.0446	0.455***	0.355***	0.323***	-0.0252	0.0132	-0.0272
	(0.110)	(0.112)	(0.112)	(0.114)	(0.109)	(0.108)	(0.120)	(0.124)	(0.120)
retired	-0.870	-0.912	-0.875	0.475	0.360	0.286	-0.872*	-0.811	-0.873*
	(0.575)	(0.621)	(0.601)	(0.388)	(0.340)	(0.349)	(0.502)	(0.526)	(0.503)
unemployed	0.503**	0.425*	0.429*	0.403	0.210	0.206	-0.499	-0.513	-0.487
	(0.223)	(0.222)	(0.226)	(0.432)	(0.386)	(0.378)	(0.400)	(0.386)	(0.399)
risk_tolerance		0.345***	0.319***		0.517***	0.494***		0.0213	0.0385
		(0.0375)	(0.0379)		(0.0345)	(0.0349)		(0.0412)	(0.0419)
constant	-0.753***	-1.353***	-1.525***	-0.923***	-1.881***	-2.285***	-1.273***	-0.823***	-1.345***
	(0.236)	(0.252)	(0.258)	(0.304)	(0.283)	(0.315)	(0.285)	(0.292)	(0.300)
Pseudo R^2	0.0319	0.0443	0.0476	0.0526	0.0947	0.0983	0.0547	0.0391	0.0549

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table XIV - Fractional Regressions for *w_comm* for 2021-2023

	2021			2022			2023		
	Model 1	**Model 2**	**Model 3**	**Model 1**	**Model 2**	**Model 3**	**Model 1**	**Model 2**	**Model 3**
financial_literacy	-0.0610		-0.0686	-0.168**		-0.155*	-0.0703		-0.0714
	(0.0652)		(0.0669)	(0.0828)		(0.0863)	(0.0680)		(0.0687)
male	0.264*	0.199	0.249*	-0.101	-0.145	-0.0773	0.127	0.0771	0.127
	(0.140)	(0.125)	(0.141)	(0.138)	(0.140)	(0.142)	(0.147)	(0.138)	(0.147)
age	0.0124**	0.0129**	0.0129**	0.00632	0.00597	0.00497	-0.00651	-0.00593	-0.00628
	(0.00633)	(0.00625)	(0.00625)	(0.00575)	(0.00591)	(0.00591)	(0.00715)	(0.00710)	(0.00714)
monthly_income	-0.0891	-0.0903	-0.0889	-0.0499	-0.0789	-0.0488	-0.203***	-0.219***	-0.204***
	(0.0759)	(0.0758)	(0.0762)	(0.0833)	(0.0779)	(0.0836)	(0.0764)	(0.0730)	(0.0763)
education	-0.128	-0.143	-0.127	0.0343	-0.00827	0.0278	-0.0709	-0.0833	-0.0709
	(0.0885)	(0.0913)	(0.0889)	(0.0865)	(0.0851)	(0.0868)	(0.0814)	(0.0820)	(0.0814)
selfemployed	0.261	0.260	0.255	0.410	0.423	0.437	0.622**	0.601*	0.619**
	(0.337)	(0.337)	(0.337)	(0.307)	(0.314)	(0.312)	(0.313)	(0.312)	(0.312)
employee	0.196	0.205	0.193	-0.117	-0.116	-0.104	0.281	0.272	0.282
	(0.197)	(0.198)	(0.197)	(0.173)	(0.178)	(0.178)	(0.214)	(0.213)	(0.214)
retired	-0.0458	-0.0333	-0.0495	-0.468	-0.479	-0.450	-0.246	-0.269	-0.246
	(0.719)	(0.707)	(0.726)	(0.502)	(0.520)	(0.508)	(0.910)	(0.907)	(0.910)
unemployed	0.0922	0.0840	0.0842	-0.110	-0.0842	-0.0986	0.806	0.813	0.799
	(0.336)	(0.341)	(0.340)	(0.479)	(0.477)	(0.487)	(0.542)	(0.535)	(0.540)
risk_tolerance		0.0212	0.0364		-0.0767	-0.0550		-0.0168	-0.0207
		(0.0596)	(0.0609)		(0.0515)	(0.0542)		(0.0730)	(0.0733)
constant	-2.165***	-2.327***	-2.250***	-1.815***	-1.925***	-1.669***	-1.538***	-1.614***	-1.497***
	(0.404)	(0.408)	(0.430)	(0.417)	(0.425)	(0.430)	(0.468)	(0.473)	(0.503)
Pseudo R^2	0.0068	0.0064	0.007	0.0072	0.0055	0.0077	0.0091	0.0086	0.0092

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table XV - Fractional Regressions for w_altern for 2021-2023

	2021			2022			2023		
	Model 1	**Model 2**	**Model 3**	**Model 1**	**Model 2**	**Model 3**	**Model 1**	**Model 2**	**Model 3**
financial_literacy	-0.122*		-0.186***	-0.0937		-0.178	-0.0378		-0.0373
	(0.0635)		(0.0625)	(0.107)		(0.112)	(0.0895)		(0.0901)
male	-0.00441	-0.342**	-0.195	0.0494	-0.177	-0.0913	0.302*	0.277*	0.302*
	(0.141)	(0.136)	(0.149)	(0.154)	(0.147)	(0.158)	(0.162)	(0.145)	(0.162)
age	-0.0291***	-0.0239**	-0.0244**	-0.0458***	-0.0381***	-0.0400***	-0.0442***	-0.0441***	-0.0443***
	(0.00995)	(0.00981)	(0.00980)	(0.00772)	(0.00755)	(0.00785)	(0.00821)	(0.00826)	(0.00832)
monthly_income	-0.0299	-0.0164	-0.0169	-0.114	-0.142*	-0.112	-0.166	-0.174*	-0.166
	(0.0740)	(0.0742)	(0.0755)	(0.0817)	(0.0753)	(0.0804)	(0.104)	(0.101)	(0.104)
education	-0.0820	-0.115	-0.0701	-0.250***	-0.251***	-0.209***	-0.208**	-0.216**	-0.208**
	(0.0920)	(0.0914)	(0.0912)	(0.0801)	(0.0723)	(0.0810)	(0.103)	(0.0982)	(0.103)
selfemployed	-0.103	-0.192	-0.173	0.185	0.0234	0.0389	1.035***	1.026***	1.036***
	(0.446)	(0.467)	(0.464)	(0.287)	(0.301)	(0.308)	(0.398)	(0.397)	(0.398)
employee	0.187	0.155	0.139	0.228	0.0927	0.128	0.438**	0.431**	0.437**
	(0.189)	(0.186)	(0.187)	(0.197)	(0.182)	(0.191)	(0.215)	(0.213)	(0.214)
retired	-0.357	-0.324	-0.382	0.919	0.721	0.812	-2.473**	-2.492**	-2.475**
	(1.022)	(1.025)	(1.031)	(1.020)	(1.044)	(1.057)	(0.990)	(0.987)	(0.989)
unemployed	-0.445	-0.548	-0.530	-0.262	-0.338	-0.321	-1.899***	-1.890***	-1.896***
	(0.362)	(0.367)	(0.364)	(0.550)	(0.525)	(0.527)	(0.717)	(0.717)	(0.717)
risk_tolerance		0.363***	0.395***		0.268***	0.294***		0.0127	0.0109
		(0.0709)	(0.0706)		(0.0627)	(0.0617)		(0.0726)	(0.0732)
constant	-0.601	-1.847***	-1.626***	0.788*	-0.292	0.0207	-0.109	-0.190	-0.130
	(0.386)	(0.434)	(0.454)	(0.448)	(0.477)	(0.510)	(0.434)	(0.463)	(0.470)
Pseudo R^2	0.0248	0.0398	0.0445	0.0583	0.0686	0.0712	0.044	0.0438	0.044

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

4.2 Mean-Variance Analysis

Building on the methodology outlined previously, this study constructs portfolios tailored to varying levels of relative risk aversion (RRA), based on Mean-Variance Theory (MVT) and Expected-Utility Theory (EUT). The aim is to compare these portfolios with average asset allocations for each level of risk tolerance (RT) and financial literacy (FL) variables (Table XVI) derived from CMVM surveys.

The MVT analysis utilises data on different ETFs to serve as benchmarks for each asset class. For the inputs used in the MVT analysis, refer to Tables A.6 and A.7 in the Appendix.

Table XVI - Average Portfolios by Risk Tolerance and Financial Literacy

	Financial Literacy Scores					**Risk Tolerance Scores**				
2021	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**
w_deposits	51.06%	47.94%	42.49%	33.03%	27.07%	59.54%	45.57%	35.31%	27.07%	12.84%
w_tbonds	3.79%	7.37%	9.94%	12.93%	14.86%	11.08%	10.80%	11.57%	9.18%	9.06%
w_cbonds	1.90%	3.69%	4.97%	6.46%	7.43%	5.54%	5.40%	5.79%	4.59%	4.53%
w_stocks	19.35%	23.33%	25.44%	32.18%	36.17%	12.74%	23.44%	31.01%	37.49%	50.84%
w_comm	10.04%	7.25%	7.02%	7.50%	6.89%	6.13%	7.42%	7.32%	7.81%	6.65%
w_altern	13.85%	10.42%	10.14%	7.89%	7.58%	4.97%	7.37%	9.01%	13.86%	16.09%
2022	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**
w_deposits	37.96%	37.32%	30.05%	24.80%	22.44%	41.73%	29.61%	17.67%	16.29%	15.53%
w_tbonds	8.33%	15.96%	23.44%	19.45%	15.47%	33.25%	20.87%	15.20%	10.40%	5.44%
w_cbonds	12.50%	4.78%	7.69%	9.48%	10.89%	6.51%	10.41%	10.02%	9.52%	6.47%
w_stocks	6.02%	22.66%	21.98%	27.57%	39.95%	6.86%	22.81%	38.17%	46.17%	52.83%
w_comm	18.52%	9.03%	10.37%	9.63%	6.17%	7.95%	10.17%	9.75%	7.77%	4.11%
w_altern	16.67%	10.25%	6.47%	9.07%	5.09%	3.69%	6.13%	9.20%	9.86%	15.62%
2023	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**
w_deposits	34.48%	34.83%	21.07%	20.77%	16.51%	22.39%	22.79%	23.79%	28.38%	30.11%
w_tbonds	30.77%	33.10%	34.86%	30.96%	28.24%	33.11%	30.96%	31.53%	34.44%	32.28%
w_cbonds	3.66%	4.45%	7.16%	8.04%	9.51%	6.66%	7.76%	6.82%	6.59%	6.40%
w_stocks	12.61%	16.70%	24.51%	27.73%	37.29%	25.76%	26.67%	27.12%	18.90%	21.13%
w_comm	5.91%	6.10%	6.88%	5.83%	4.51%	5.53%	6.38%	5.18%	5.03%	5.36%
w_altern	12.57%	4.82%	5.52%	6.68%	3.93%	6.54%	5.43%	5.56%	6.66%	4.72%

For the 2021 analysis (Table XVII), optimal portfolios vary between investing only in 2 ETFs or in 4 ETFs and deposit. The tangent (T) portfolio maximises the Sharpe Ratio by investing in all ETFs, except the one capturing commodities.

Table XVII - Compositions and basic statistics for T and MV portfolios and optimal MVT portfolios for RRA = {-1,0,1,2,3,4,5,6} for 2021

RRA	**-1**	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**MV**	**T**
Deposits	0.000	0.000	0.000	0.000	0.000	0.000	0.049	0.228	0.000	0.000
T-bonds	0.000	0.000	0.306	0.374	0.397	0.340	0.300	0.252	0.244	0.316
C. Bonds	0.000	0.000	0.000	0.288	0.371	0.495	0.523	0.411	0.721	0.551
Stocks	0.076	0.076	0.184	0.094	0.077	0.053	0.042	0.036	0.002	0.044
Commodities	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.033	0.000
Altern.	0.924	0.924	0.510	0.245	0.155	0.112	0.085	0.072	0.000	0.089
Expected Return	1.452	1.452	0.829	0.418	0.280	0.213	0.169	0.140	0.034	0.177
Volatility	0.661	0.661	0.370	0.181	0.119	0.090	0.071	0.060	0.034	0.075
Sharpe Ratio	2.205	2.205	2.256	2.339	2.400	2.434	2.444	2.443	1.136	2.444

In Figure 1, as the risk tolerance level increases from the 2021 Survey, both portfolio volatility and expected return also increase. Risk tolerance score 1 exhibits lower risk than $RRA = 6$, while scores 2 and 3's risk closely resemble $RRA = 5$ and $RRA = 4$ portfolios' risk, respectively. Risk levels for RT levels 4 and 5 exhibit higher risk levels than the optimal portfolio for $RRA = 3$.

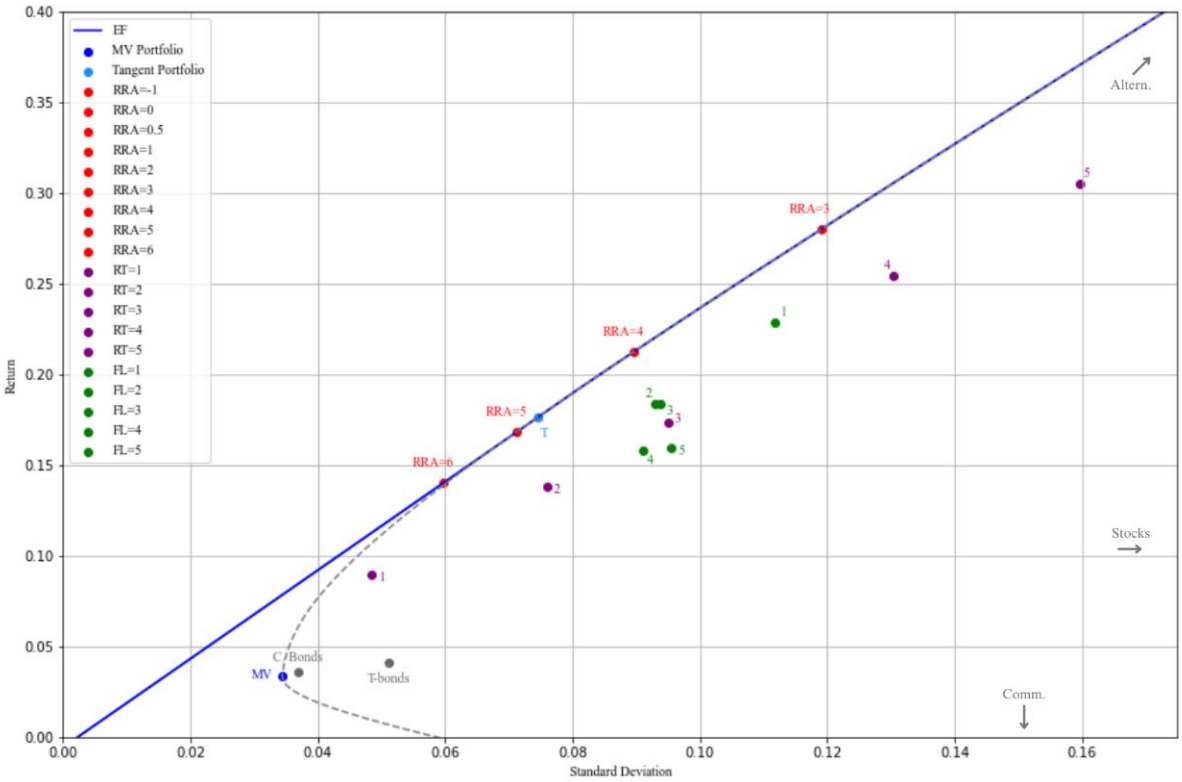

Figure 1 - Mean-variance representation of all portfolios and the EF for 2021

The portfolio returns for the FL scores tend to roughly align with the returns for the $RRA = 5$ portfolio, except for the lowest literacy level. The risk for portfolios for scores 2, 3, 4, and 5 align closely with $RRA = 4$, while for score 1, it falls between $RRA = 3$ and $RRA = 4$. The portfolio for score 1 of FL exhibits higher risk, suggesting that lower literacy may affect the perception of risk.

Considering that real life RRA varies between 0 and 3, it can be argued that the average portfolios for $RT = \{1,2,3\}$ and $FL = \{1,2,3,4,5\}$ are ultraconservative. Nonetheless, the average portfolios for $RT = \{4,5\}$ can still be deemed as conversative.

It should be noted that the mean-variance representations of the average financial literacy (FL) and risk tolerance (RT) portfolios at each level incorporate the allocation of funds in the risk-free asset as deposits. Despite this, the representations of the RT and FL portfolios fall below the efficient frontier (EF).

In the 2022 MVT analysis (Table XVIII), optimal portfolios for each RRA range from investing solely in 2 ETFs to including 4 ETFs along with deposits. The tangent (T) portfolio invests in all ETFs except the one capturing commodities, similarly to 2021.

Table XVIII - Compositions and basic statistics for T and MV portfolios and optimal MVT portfolios for RRA = {-1,0,1,2,3,4,5,6} for 2022

RRA	**-1**	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**MV**	**T**
Deposits	0.000	0.000	0.000	0.000	0.000	0.000	0.029	0.215	0.000	0.000
T-bonds	0.000	0.000	0.187	0.332	0.384	0.328	0.301	0.232	0.253	0.305
C. Bonds	0.000	0.000	0.000	0.258	0.358	0.484	0.526	0.434	0.703	0.546
Stocks	0.047	0.049	0.338	0.183	0.111	0.084	0.064	0.052	0.000	0.066
Commodities	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.044	0.000
Altern.	0.953	0.951	0.474	0.227	0.146	0.104	0.080	0.067	0.000	0.083
Expected Return	1.530	1.527	0.806	0.407	0.274	0.206	0.166	0.137	0.033	0.172
Volatility	0.759	0.758	0.389	0.190	0.125	0.093	0.075	0.062	0.035	0.078
Sharpe Ratio	2.018	2.018	2.077	2.148	2.199	2.230	2.238	2.238	1.018	2.238

Consistent with the 2021 results, the average portfolio for the financial literacy score of 1 displays the highest volatility. As in the 2021 analysis, there is an upward trajectory in the risk levels of average portfolios as risk tolerance increases (Figure 2).

Most average portfolios for the FL and RT scores are ultraconservative, evidenced by their risk levels being lower than the risk of the $RRA = 3$ optimal portfolio.

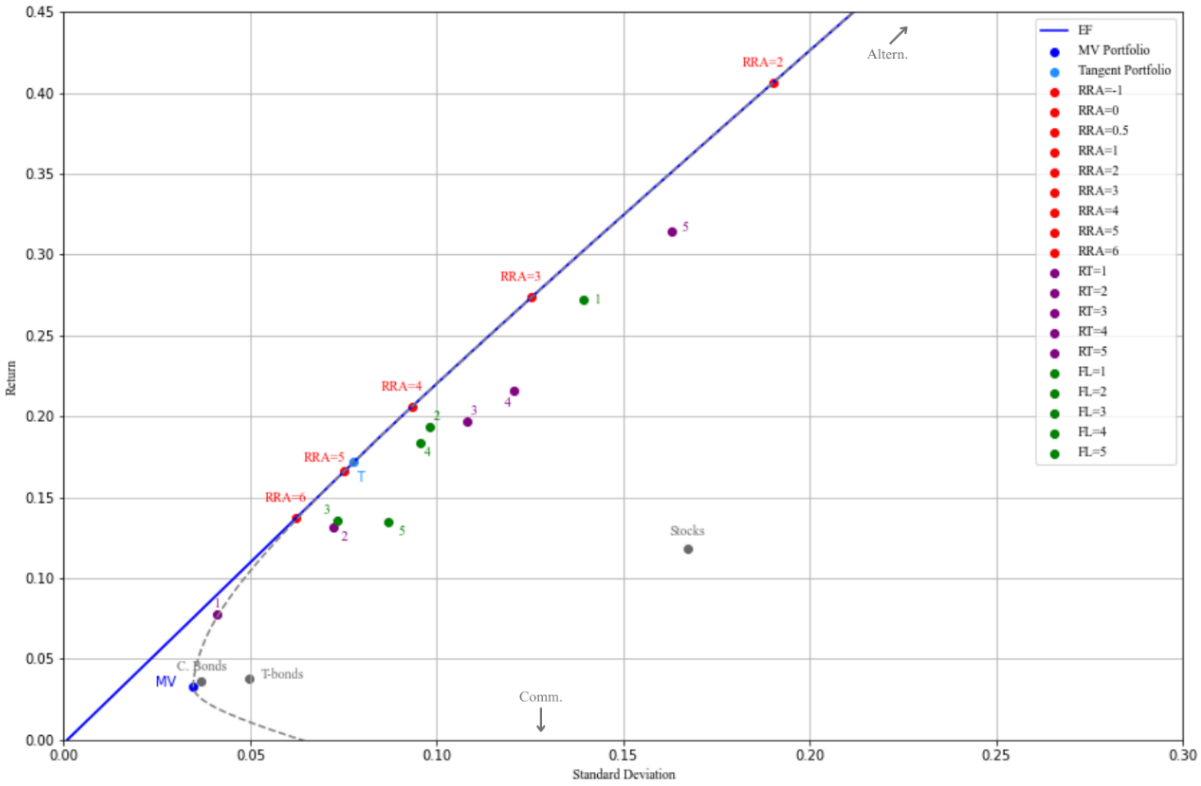

Figure 2 - Mean-variance representation of all portfolios and the EF for 2022

For the 2023 analysis (Table XIX), the optimal portfolios across the RRA levels range from exclusively investing in 2 ETFs to including 2 ETFs along with deposits. The tangent portfolio also only invests in 2 ETFs.

Table XIX - Compositions and basic statistics for T and MV portfolios and optimal MVT portfolios for RRA = {-1,0,1,2,3,4,5,6} for 2023

RRA	**-1**	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**MV**	**T**
Deposits	0.000	0.000	0.001	0.495	0.663	0.747	0.798	0.828	0.000	0.000
T-bonds	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.200	0.000
C. Bonds	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.754	0.000
Stocks	0.028	0.028	0.509	0.258	0.172	0.129	0.104	0.088	0.000	0.509
Commodities	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.046	0.000
Altern.	0.972	0.972	0.489	0.248	0.165	0.124	0.098	0.083	0.000	0.491
Expected Return	0.965	0.965	0.529	0.280	0.195	0.153	0.127	0.111	0.007	0.530
Volatility	0.933	0.933	0.494	0.250	0.166	0.125	0.099	0.084	0.040	0.495
Sharpe Ratio	1.007	1.007	1.022	1.022	1.022	1.022	1.022	1.022	-0.457	1.022

It should be highlighted, as previously mentioned, that the returns for the average FL and RT portfolios incorporate the return from investing in deposits. This explains why these portfolios are placed outside the hyperbola, in Figure 3. Adjusting for the deposit

weights, the average portfolios for each RT and FL level align roughly on or slightly below the hyperbola. This positioning also means that these portfolios are below the EF.

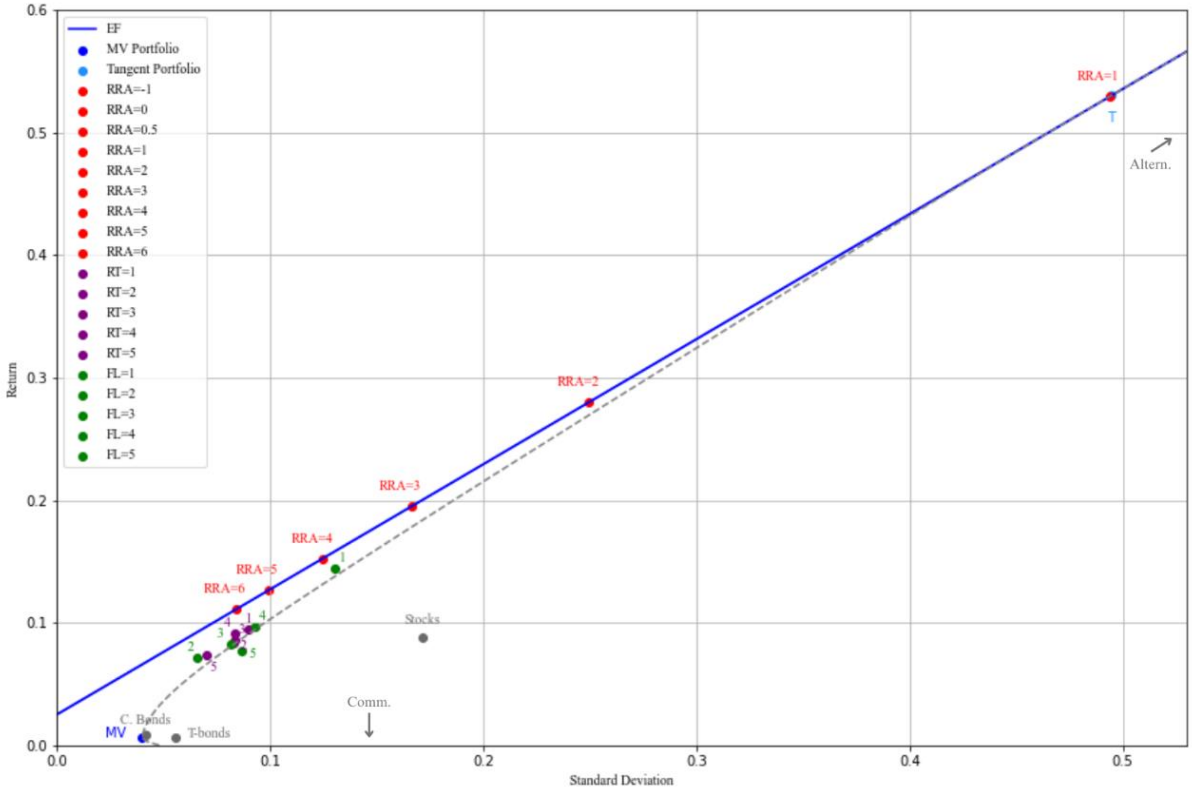

Figure 3 - Mean-variance representation of all portfolios and the EF for 2023

Consistent with the analyses from previous years, the average portfolio for financial literacy score 1 exhibits the highest level of risk (Figure 3). However, the average RT portfolios show a clustered pattern, diverging from the previous results, likely due to the dataset limitations previously identified. In 2023, all average portfolios for FL and RT are ultraconservative, as their risk levels are lower than those exhibited by the $RRA = 3$ portfolio.

5. CONCLUSION

This study examines risk tolerance and financial literacy as determinants of asset allocation choices, employing fractional regression analysis.

These results are based on specific samples, which are heavily reliant on their communication and distribution channels and subject to measurement error, such as misunderstandings of the questions by respondents, or errors in recording responses. The robustness check through the years is also dependent on the adjustments made to make the three surveys comparable.

A common pattern in the analysis is the crude and limited nature of the 2023 risk tolerance measure, due to limitations inherent to the survey and variable construction. Nonetheless, it sometimes arises as significant, suggesting it captures some effect.

Financial literacy has a positive and significant relationship with the weight in investors' portfolios allocated to corporate bonds and stocks/equity funds, consistent with past literature. Financial literacy decreases the percentage allocated to deposits, commodities, and alternative investments within individuals' portfolios, although are not always statistically significant over the years. Financial literacy drives individuals be less inclined towards low-risk options and opt for more complex alternatives.

Conversely, we find that risk tolerance negatively correlates with the portfolio percentage allocated in asset classes that are deemed as mostly risk-free, such as deposits and treasury bonds and is positively associated with the percentage of the portfolio allocated to stocks/equity funds and alternative investments. The relationships with commodities and corporate bonds are not clear or lack robustness through the years.

Furthermore, we also note that for most of the asset classes the direction of the relationship with risk tolerance and financial literacy align, suggesting that there is indeed a positive correlation between these two variables, consistent with Bajo et al. (2015).

In terms of the mean-variance analysis, it seems that the average portfolios for each risk tolerance and financial literacy scores do not seem to follow mean-variance efficiency. The average Portuguese investor, for each level of the risk tolerance and financial literacy, is conservative or ultraconservative. This analysis is however contingent on a small number of ETFs, representing each asset class.

Future research may explore the generalisability of the results identified for Portuguese investors to other nationalities at the European level. In terms of methodology, using the multivariate generalisation of the fractional logit model, as proposed by Buis (2008), may offer a robust alternative, since it ensures that for each observation, a set of fractional dependent variables add up to 1. Moreover, the separate effects of the subjective and objective financial literacy measures on the percentage allocation of each asset class could also be explored in future studies.

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APPENDIX

Table A.1 - Survey Questions and Variable Definition

Survey Question	Variable
(1) Please indicate your gender. A. Male B. Female C. Other	*male*
(2) Please indicate your age.	*age*
(3) What is the highest level of education you have completed? 1. Primary education (4th grade) 2. Basic education (9th grade) 3. Secondary education (12th grade) 4. Currently enrolled in higher education 5. Higher education (polytechnic or university) 6. Master's degree, MBA, or PhD	*education*
(4) What is your current employment/labour status?	
A. Student/Working Student	
B. Self-employed	*selfemployed*
C. Employed (working for someone else)	*employee*
D. Unemployed	*unemployed*
E. Retired	*retired*
G. Other	
(5) What is your household's monthly net income bracket? 1. Up to 500 € 2. Between 501 and 1000 € 3. Between 1001 and 2500 € 4. Between 2501 and 5000 € 5. More than 5000 €	*monthly_income*
(6) Suppose you have 100,000 Euros to invest in the following options. How much would you invest in each of them?	
A. Deposits	*w_deposits*
B. Treasury Bonds	*w_tbonds*
C. Corporate Bonds	*w_cbonds*
D. Stocks & Equity investment funds	*w_stocks*
E. Commodities	*w_comm*
F. Alternative Investments	*w_altern*
2022 & 2023 Surveys: Objective Financial Literacy	
(7) Suppose you had €100 in a savings account and the interest rate was 2% per year. After 5 years, how much do you think you would have in the account if you left the money to grow? A. More than €110 B. Exactly €110 C. Less than €110 D. I do not know/No answer	

(8) Suppose you have €100 in a bank account with an annual interest rate of 2% and the inflation rate is 3% per year. In a year's time, what do you think you would be able to buy with the money from this account, knowing that you do not make any more deposits, withdraw any money from the account, and there are no taxes or fees? A. You would buy fewer things than today B. You would buy the same things as today C. You would buy more things than today D. I do not know/No answer **(9)** You invested in a bond that pays a fixed coupon rate. Meanwhile, market interest rates have risen. If you sell this bond after this increase, the price of the bond should be: A. Higher than the price at which you bought it B. Equal to the price at which you bought it C. Lower than the price at which you bought it D. I do not know/No answer **(10)** A 15-year loan typically requires higher monthly payments than a 30-year loan, but the total interest paid over the life of the loan will be lower. A. True B. False C. I do not know/No answer **(11)** Investing in stocks of a single company generally offers a safer return than investing in a stock mutual fund. A. True B. False C. I do not know/No answer	$financial\_literacy$: ordinal numerical variable, ranging from 1 to 5. Higher values account for higher financial literacy levels. Built based on the correct answers provided to the financial literacy questions and the subjective literacy indicated by the respondent (see Questions 13 and 14 below).
2021 Survey: Objective Financial Literacy	
The mortgage-related question is absent from the 2021 Survey, and no comparable alternative is available. Thus, the 2021 dataset includes a question regarding the relationship between structured products and their underlying assets. See below. **(12) (in alternative)** The performance of a Structured Product depends, among other factors, on the evolution of the underlying financial assets of the product. A. True B. False C. I do not know/No answer	
2023 & 2021 Surveys: Subjective Financial Literacy	
(13) Rate your knowledge of financial markets and products. 1. Not knowledgeable 2. Slightly knowledgeable 3. Knowledgeable 4. Moderately knowledgeable 5. Very knowledgeable	$financial\_literacy$

2022 Survey: Subjective Financial Literacy	
(14) Rate your financial knowledge compared to the average Portuguese population? 1. Considerably below average 2. Below average 3. Equal to average 4. Above average 5. Considerably above average	$financial\_literacy$
2023 Survey: Risk Tolerance Question(s)	
(15) Suppose you can invest in a financial product that offers an equal chance of losing 50 euros or gaining X euros. What is the minimum value you would require for the gain X to invest in this financial product?	$risk\_tolerance$
2022 Survey: Risk Tolerance Question(s)	
(16) How would you classify your attitude towards financial risk? 1. Very risk-averse / I really dislike taking risks. 2. Risk-averse / I don't like taking risks. 4. Risk-loving / I enjoy taking risks. 5. Very risk-loving / I enjoy taking risks a lot. **(17)** What are you looking for in your financial investments? 1. Guaranteed capital, without risk. 2. Preserving the value of the investment, assuming minimal risk. 3. Increasing invested capital with a slightly higher return than the money market interest rate with moderate risk. 4. Achieving an annual return significantly higher than the money market interest rate, accepting that to achieve this, the level of risk incurred will be higher and correlated with the market. 5. Seeking maximum possible return, regardless of significantly increasing risk and/or it being very high.	$risk\_tolerance$
2021 Survey: Risk Tolerance Question(s)	
(18) How would you classify your attitude towards financial risk? 1. Very risk-averse / I really dislike taking risks. 2. Risk-averse / I don't like taking risks. 3. Neutral towards risk / I neither like nor dislike taking risks. 4. Risk-loving / I enjoy taking risks. 5. Very risk-loving / I enjoy taking risks a lot.	
(19) Suppose you can make an investment with a 50% chance of earning €100 and a 50% chance of losing money. Would you accept or reject each of the four different loss scenarios are presented below investment? (a) 50% chance of gaining €100 & 50% chance of losing €10. (b) 50% chance of gaining €100 & 50% chance of losing €25. (c) 50% chance of gaining €100 & 50% chance of losing €50. (d) 50% chance of gaining €100 & 50% chance of losing €100	$risk\_tolerance$

Table A.2 - Descriptive Statistics for 2021-2023

Variable	2021					2022					2023				
	Count	**Mean**	**Std. Dev.**	**Min.**	**Max.**	**Count**	**Mean**	**Std. Dev.**	**Min.**	**Max.**	**Count**	**Mean**	**Std. Dev.**	**Min.**	**Max.**
age	1052	32.6768	13.8077	18	77	922	36.085	13.903	18	82	1143	35.163	14.2439	18	87
male	1052	0.5475	0.4980	0	1	922	0.6085	0.4884	0	1	1148	0.5897	0.4921	0	1
education	1052	4.9354	1.0031	1	6	919	5.0218	0.9575	1	6	1143	5.0166	0.9257	1	6
monthly_income	999	2.3564	1.0599	1	5	916	3.3472	0.8917	1	5	1135	3.3366	0.8583	1	5
financial_literacy	1047	3.2311	1.1310	1	5	920	3.9728	0.9048	1	5	1144	3.4738	1.0889	1	5
employee	1052	0.4278	0.4950	0	1	922	0.4664	0.4991	0	1	1148	0.4399	0.4966	0	1
selfemployed	1052	0.0485	0.2149	0	1	922	0.051	0.2201	0	1	1148	0.0531	0.2244	0	1
unemployed	1052	0.0257	0.1582	0	1	922	0.0163	0.1266	0	1	1148	0.0122	0.1098	0	1
retired	1052	0.0086	0.0921	0	1	922	0.0163	0.1266	0	1	1148	0.0105	0.1017	0	1
risk_tolerance	1052	2.6911	1.0381	1	5	910	2.6473	1.1893	1	5	1148	2.1263	0.9778	1	5
w_deposits	1052	0.3920	0.3246	0	1	922	0.2593	0.2578	0	1	1148	0.2337	0.2793	0	1
w_tbonds	1052	0.1057	0.1344	0	0.6667	922	0.1853	0.2237	0	1	1148	0.3175	0.2987	0	1
w_cbonds	1052	0.0528	0.0672	0	0.3333	922	0.0926	0.1294	0	1	1148	0.0723	0.1275	0	1
w_stocks	1052	0.2832	0.2479	0	1	922	0.2984	0.2660	0	1	1148	0.2604	0.2644	0	1
w_comm	1052	0.0734	0.1336	0	1	922	0.0884	0.1557	0	1	1148	0.0588	0.1228	0	1
w_altern	1052	0.0930	0.1720	0	1	922	0.0760	0.1439	0	1	1148	0.0572	0.1301	0	1

Table A.3 - Correlation Matrix for 2021

	financial_literacy	*risk_tolerance*	*age*	*monthly_income*	*education*	*employee*	*selfemployed*	*unemployed*	*retired*	*male*
financial_literacy	1	0.276	0.062	0.076	0.159	N/A	N/A	N/A	N/A	N/A
risk_tolerance	0.276	1	-0.121	-0.059	-0.066	N/A	N/A	N/A	N/A	N/A
age	0.062	-0.121	1	0.542	0.561	N/A	N/A	N/A	N/A	N/A
monthly_income	0.076	-0.059	0.542	1	0.452	N/A	N/A	N/A	N/A	N/A
education	0.159	-0.066	0.561	0.452	1	N/A	N/A	N/A	N/A	N/A
employee	N/A	N/A	N/A	N/A	N/A	1	N/A	N/A	N/A	-0.012
selfemployed	N/A	N/A	N/A	N/A	N/A	N/A	1	N/A	N/A	0.192
unemployed	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1	N/A	-0.077
retired	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1	0.002
male	N/A	N/A	N/A	N/A	N/A	-0.012	0.192	-0.077	0.002	1

Table A.4 - Correlation Matrix for 2022

	financial_literacy	*risk_tolerance*	*age*	*monthly_income*	*education*	*employee*	*selfemployed*	*unemployed*	*retired*	*male*
financial_literacy	1	0.231	0.052	0.263	0.253	N/A	N/A	N/A	N/A	N/A
risk_tolerance	0.231	1	-0.241	-0.006	-0.123	N/A	N/A	N/A	N/A	N/A
age	0.052	-0.241	1	0.344	0.423	N/A	N/A	N/A	N/A	N/A
monthly_income	0.263	-0.006	0.344	1	0.304	N/A	N/A	N/A	N/A	N/A
education	0.253	-0.123	0.423	0.304	1	N/A	N/A	N/A	N/A	N/A
employee	N/A	N/A	N/A	N/A	N/A	1	N/A	N/A	N/A	0.205
selfemployed	N/A	N/A	N/A	N/A	N/A	N/A	1	N/A	N/A	0.074
unemployed	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1	N/A	0.213
retired	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1	0.055
male	N/A	N/A	N/A	N/A	N/A	0.205	0.074	0.213	0.055	1

Table A.5 - Correlation Matrix for 2023

	financial_literacy	*risk_tolerance*	*age*	*monthly_income*	*education*	*employee*	*selfemployed*	*unemployed*	*retired*	*male*
financial_literacy	1	-0.051	0.110	0.262	0.200	N/A	N/A	N/A	N/A	N/A
risk_tolerance	-0.051	1	0.160	0.012	0.070	N/A	N/A	N/A	N/A	N/A
age	0.110	0.160	1	0.262	0.487	N/A	N/A	N/A	N/A	N/A
monthly_income	0.262	0.012	0.262	1	0.211	N/A	N/A	N/A	N/A	N/A
education	0.200	0.070	0.487	0.211	1	N/A	N/A	N/A	N/A	N/A
employee	N/A	N/A	N/A	N/A	N/A	1	N/A	N/A	N/A	0.187
selfemployed	N/A	N/A	N/A	N/A	N/A	N/A	1	N/A	N/A	-0.042
unemployed	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1	N/A	0.261
retired	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1	0.300
male	N/A	N/A	N/A	N/A	N/A	0.187	-0.042	0.261	0.300	1

Table A.6 – Historical Returns for the selected ETFs (2021-2023)

	T-bonds	C. Bonds	Stocks	Comm.	Alternat.
2021	4.08%	3.59%	10.74%	-7.59%	156.21%
2022	3.80%	3.63%	11.79%	-4.44%	159.90%
2023	0.62%	0.89%	8.77%	-2.58%	99.00%

Table A.7 – Variance-Covariance Matrices for selected ETFs (2021-2023)

	2021					**2022**					**2023**				
T-bonds	0.0026	0.0008	0.0004	-0.0002	0.0017	0.0024	0.0008	0.0006	-0.0002	0.0017	0.0031	0.0013	0.0009	-0.0003	0.0032
C. Bonds	0.0008	0.0014	0.0011	0.0005	0.0025	0.0008	0.0014	0.0014	0.0007	0.0029	0.0013	0.0017	0.0021	0.0009	0.0054
Stocks	0.0004	0.0011	0.0364	0.0071	0.0123	0.0006	0.0014	0.0280	0.0065	0.0161	0.0009	0.0021	0.0295	0.0058	0.0312
Comm.	-0.0002	0.0005	0.0071	0.0254	0.0046	-0.0002	0.0007	0.0065	0.0170	0.0066	-0.0003	0.0009	0.0058	0.0212	0.0110
Altern.	0.0017	0.0025	0.0123	0.0046	0.5092	0.0017	0.0029	0.0161	0.0066	0.6326	0.0032	0.0054	0.0312	0.0110	0.9201
	T-bonds	C.Bonds	Stocks	Comm.	Altern.	T-bonds	C.Bonds.	Stocks	Comm.	Altern.	T-bonds	C.Bonds.	Stocks	Comm.	Altern.

DISCLAIMER

This master thesis was developed with strict adherence to the academic integrity policies and guidelines set forth by ISEG, Universidade de Lisboa. The work presented herein is the result of my own research, analysis, and writing, unless otherwise cited. In the interest of transparency, I provide the following disclosure regarding the use of artificial intelligence (AI) tools in the creation of this thesis:

I disclose that AI tools were employed during the development of this thesis as follows:

- Generative AI tools were consulted for brainstorming and outlining purposes.
- AI tools were used for linguistic checking and refinement.

However, all final writing, synthesis, and critical analysis are my own work. Instances where AI contributions were significant are clearly cited and acknowledged.

Nonetheless, I have ensured that the use of AI tools did not compromise the originality and integrity of my work. All sources of information, whether traditional or AI-assisted, have been appropriately cited in accordance with academic standards. The ethical use of AI in research and writing has been a guiding principle throughout the preparation of this thesis.

I understand the importance of maintaining academic integrity and take full responsibility for the content and originality of this work.

Inês Filipa Rico Lopes

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