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Citation for published version:

Lin, C & Bates, TC 2022, 'Smart people know how the economy works: Cognitive ability, economic knowledge and financial literacy', *Intelligence*, vol. 93, 101667. <https://doi.org/10.1016/j.intell.2022.101667>

Digital Object Identifier (DOI):

[10.1016/j.intell.2022.101667](https://doi.org/10.1016/j.intell.2022.101667)

Link:

[Link to publication record in Edinburgh Research Explorer](#)

Document Version:

Publisher's PDF, also known as Version of record

Published In:

Intelligence

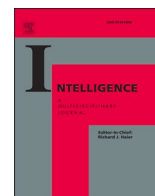
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Smart people know how the economy works: Cognitive ability, economic knowledge and financial literacy

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ARTICLE INFO

Keywords:

Economic knowledge
Cognitive ability
Financial literacy
Financial knowledge

ABSTRACT

Cognitive ability correlates positively with many financial outcomes but why? One important relationship to understand is the degree to which cognitive ability is associated with greater knowledge of economics, but this has not been tested extensively. Here in two large, pre-registered studies ($N = 1356$), we tested the relationship between cognitive ability and both economic knowledge and financial literacy. Three predictions were key: i) Cognitive ability would show a large positive association with economic knowledge; ii) Cognitive ability would be associated with better financial literacy and iii) Greater economic knowledge would be positively associated with financial literacy. All three predictions were supported and replicated. Cognitive ability predicted economic knowledge ($r = 0.37$ to 0.52) independent of and with much larger effects than either educational attainment or economics courses. The findings extend effects of general ability to include greater awareness of economic functions, and improved use of economic information which improves lifetime financial wellbeing.

1. Introduction

“Economics is everywhere, and understanding economics can help you make better decisions and lead a happier life.” Tyler Cowen (2007).

Economic knowledge and financial literacy are crucial for making informed political and financial decisions. Cognitive ability may play an important role in raising both. If so, this would help explain why cognitive ability is correlated with nearly all positive financial outcomes from income (Ceci & Williams, 1997), to returns earned in the stock market (Grinblatt, Keloharju, & Linnainmaa, 2012). Several studies have examined the association of ability and financial literacy (Herd, Holden, & Su, 2012; Hsu, 2016; Li et al., 2015; Li, Baldassi, Johnson, & Weber, 2013). By contrast, few studies have tested the association of ability with economic knowledge, often focussing on specific knowledge, for instance of inflation (D'Acunto, Hoang, Paloviita, & Weber, 2019), rather than more general measures. Mediation among these variables, for instance by education is also under-researched. Here, we conducted two studies examining i) The relationship of cognitive ability to economic knowledge, ii) The relationship of cognitive ability to financial literacy, iii) The relationship between ability, economic knowledge and financial literacy, and iv) Mediation of these effects by education and economic training. Before presenting these studies, we briefly outline measurement of economic knowledge and economic

literacy, and findings in these areas.

1.1. Aim1: economic knowledge and cognitive ability

Economics is concerned with the production, exchange, and allocation of resources (Mankiw & Taylor, 2020; Sloman, Guest, & Garratt, 2018). Economics itself has risen to become one of the most popular fields of study in higher education (Brückner et al., 2015) and along with this, tests of economic knowledge have been developed and validated. By contrast with tests of economic attitudes (e.g. Lewis & Bates, 2018), economic knowledge tests specific facts, understanding of causal relationships in economic activities, and key concepts of economics (Walstad & Soper, 2010; Wobker, Lehmann-Waffenschmidt, Kenning, & Gigerenzer, 2012). Defined this way, economic knowledge can be seen to involve knowledge, understanding, and reasoning about how a system works – processes featuring prominently in definitions of cognitive ability (Legg & Hutter, 2007). This lead us to predict a strong association of cognitive ability with economic knowledge. Surprisingly, however, tests of this relationship are limited. For instance D'Acunto et al. (2019) report that intelligence is correlated with knowledge of inflation, and Jedinger and Burger (2021) found that political knowledge (perhaps cognate to economic knowledge) was associated with cognitive ability. Since inflation is only one among many important economic concepts

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<https://doi.org/10.1016/j.intell.2022.101667>

Received 3 February 2022; Received in revised form 14 June 2022; Accepted 14 June 2022

Available online 22 June 2022

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(Wobker et al., 2012), and because politics can vary widely independent of understanding of economics, the relationship between cognitive ability and economic knowledge cannot be said to have been verified as yet. We therefore aimed to determine, in two large samples, the association of general ability with a well validated and comprehensive measure of economic knowledge. A second aim was to replicate an association of cognitive ability with financial literacy (which has been the focus of more research with cognitive ability), and we turn to this next.

1.2. Aim2: cognitive ability and financial literacy

If greater cognitive ability leads to greater understanding of economic mechanisms, this raises a second question: Do brighter people also perform better in managing their money? This trait of successful practical management of money and financial resources is known as financial literacy, defined as “the ability to make informed judgements and take effective decisions regarding the use and management of money” (Noctor, Stoney, & Stradling, 1992) and “an ability to use knowledge and skills to manage financial resources effectively for a lifetime of financial wellbeing” (U.S. Financial Literacy and Education Commission, 2006). Measures of financial literacy correlate with multiple outcomes indicative of lifetime financial wellbeing, from retirement planning and precautionary savings behaviour (Anderson, Baker, & Robinson, 2017), as well as spending versus saving for the future (Wagner & Walstad, 2019), and understanding of risk, and of concepts such as compound interest (Inderst et al., 2013).

Several studies have examined the association of cognitive ability and measures of financial literacy, finding positive effects ranging from 0.11 to 0.61 (Delavande, Rohwedder, & Willis, 2008; Kramer, 2012; Muñoz-Murillo, Álvarez-Franco, & Restrepo-Tobón, 2020; Skagerlund, Lind, Strömbäck, Tinghög, & Västfjäll, 2018). While some of these effects used specifically numerical or even financial measures of cognition (e.g. the cognitive reflection test, number series or even assessments of a specific financial competence such as calculating interest, e.g. (Hung, Parker, & Yoong, 2009; Stella, Filotto, & Cervellati, 2020)), other studies have used broad ability batteries, suggesting the association generalises to general ability rather than a specific learned capability (Finke, Howe, & Huston, 2017; Gaurav & Singh, 2012; Herd et al., 2012; Li et al., 2013; Li et al., 2015; Lusardi, Mitchell, & Curto, 2010). Further validating the association of cognitive ability with financial capability also predicts objective economic outcomes including increased stock market participation (Grinblatt, Keloharju, & Linnainmaa, 2011), increased returns earned in stock trades (Grinblatt et al., 2012), active economic choices such as mutual fund choice (Grinblatt, Ikäheimo, Keloharju, & Knüpfer, 2016) and fewer financial mistakes, for instance when using credit card or applying for loan (Agarwal & Mazumder, 2013). Here, we aimed to further validate this association, using a multi-component measure of financial literacy and placing this in the context of economic knowledge and potential mediating effects of education.

1.3. Aim3: education as a mediator?

Education correlates positively with economic understanding (Gleason & Van Scyoc, 1995) and financial literacy (Atkinson & Messy, 2012). Given the association of intelligence with years of education (Ceci & Williams, 1997; Ritchie, Bates, & Deary, 2015; Strenze, 2007), it might be thought that any association of general ability with specific economic knowledge, or financial literacy, then this is an artifact of exposure to education. Contrarily, ability may cause both increased years of education and increased economic knowledge and financial literacy. It is important, therefore, to test whether education accounts for all or some of any association observed between intelligence and economic knowledge. Some evidence suggests that education *does not* account for higher economic knowledge in brighter individuals. D'Acunto et al. (2019) for instance, report that cognitive ability still predicted knowledge of the effects of inflation even controlling for

education level. Evidence for the role of education, or even specific training on economic knowledge and financial literacy is insufficiently well established.

To address these aims, in study 1 we used a validated measure of economic knowledge, a multifactorial measure of financial literacy, and a wide-ranging measure of cognitive ability to 1) test the association of cognitive ability with economic knowledge; and 2) test the association of cognitive ability with financial literacy; 3) test whether economic knowledge might mediate this association and 4) test dependence of these effects on commonly predicted mediating effects of education.

2. Study 1

We set out to gain a large sample, with a recognised broad-spectrum measure of general cognitive ability, an established measure of economic knowledge, and a comprehensive measure of financial literacy. This would permit testing the association of cognitive ability with economic knowledge, replicating the association of ability with financial literacy, and testing the associations among these three constructs. We also wished to control for confounders, in particular education. Based on earlier work, we predicted that cognitive ability would predict broadly measured economic knowledge even controlling for education.

Adequate assessment of financial literacy requires testing multiple components. In selecting measures of financial literacy we were guided by Hung et al. (2009) and Stella et al. (2020), including multiple components of financial literacy including financial knowledge, e.g. how interest rates are linked to bond prices, competent financial behaviours in matters of credit, investment, loans, etc. e.g. having a personal retirement account, and preference for considered rather than impulsive purchases. Subscales from Allgood and Walstad (2016) and Inderst et al. (2013) were selected to match this model, with a total of 35 items.

We tested the hypotheses that 1) Cognitive ability would be a strong predictor of economic knowledge, 2) Cognitive ability will be positively correlated with financial literacy, and 3) Economic knowledge will be positively correlated with financial literacy. We also tested if these associations survive controlling for the other in this triad, and for confounders of age, gender, household income, and education level. Predictions and sample size were pre-registered on [AsPredicted.org](https://www.aspredicted.org).

3. Methods

3.1. Subjects

A total of 656 participants were recruited using Prolific Academic, an online platform for recruiting subjects for research (473 females, mean age 39.25 years, minimal age = 20, maximal age = 75, SD = 12.60). The Prolific participant panel is large (> 134,000 active adult volunteers) and with similar socioeconomic status, ethnic background, and income distributions to the national average. We pre-registered a criterion that subjects who completed the questionnaire <1 min would be excluded. No subjects met this criterion. The racial mix of the sample was representative of the UK, with participants identifying as White ($n = 590$; 89.9%), Asian ($n = 24$; 3.6%), Mixed ($n = 24$; 3.6%), Black ($n = 17$; 2.5%) and other ($n = 1$; 0.1%). The distribution of household income of samples was close to general population, but the percentage of participants who attained a bachelor's or equivalent tertiary education degree was higher than general population in our sample. The study was approved by the Psychology Research Ethics Committee at the School of Philosophy, Psychology & Language Sciences in the University of Edinburgh. All participants gave informed consent.

3.2. Measures and procedure

To assure construct coverage, each was measured with multiple indicators. Cognitive ability was measured using three scales from the reliable and well-validated International Cognitive Ability Resource

(Revelle et al., 2014): Verbal Reasoning, Letter and Number Series, and Matrix Reasoning. Verbal Reasoning included 16 questions of logic, vocabulary and general knowledge, example items include “The opposite of a “stubborn” person is a ‘ ___ ’ person”. The Coefficient omega of Verbal Reasoning scale was 0.72 in our sample. Letter and Number Series included 9 items. An example is “In the following number series, what number comes next? 4, 7, 11, 18, 29, ...”. The Coefficient omega of Letter and Number Series scale was 0.87 in our sample. Matrix Reasoning scale consisted of 11 items based on 3×3 arrays of geometric shapes with one of the nine shapes missing. Participants had to select the shape that would complete the array from 6 options. The Coefficient omega of Matrix Reasoning scale was 0.78 in our sample. Factor scores of Verbal Reasoning, Letter and Number Series, and Matrix Reasoning were combined to form a total cognitive ability score.

The *Test of Economic Knowledge* (Walstad & Soper, 2010) consists of 40 multiple choice questions related to objective economic phenomenon. Each question has 4 options, with example items including “Why are diamonds more expensive than water even though water is necessary for life and diamonds are not”. For use in the UK, we replaced US-specific terms “US (to UK)”, “Federal Reserve System (Bank of England)”, “Internal Revenue Service (Her Majesty’s Revenue and Customs)”, “Department of Commerce (Department for International Trade)” and “Federal Trade Commission (Competition and Markets Authority)”. The Coefficient omega reliability of the test in our sample was 0.86.

Financial literacy was measured using scales from Allgood and Walstad (2016) and Inderst et al. (2013) assessing financial knowledge, competence, and time preference across a total of 35 items. The financial knowledge component consists of 6 questions covering understanding of financial including interest rates, stocks, and bonds as well as participant’s confidence in their overall financial knowledge (Allgood & Walstad, 2016). Coefficient omega of the first five items in financial knowledge was 0.37 in our sample. Although the financial knowledge scale showed a relative lower reliability, structural modelling supported a one-factor solution with all items loading on this latent variable. The next financial literacy component, financial competence, was measured with 22 True/False questions across five areas: credit card use, investment, loan, insurance, and financial advice taking (Allgood & Walstad, 2016). An example item is “How many times have you been late with your mortgage payments in the last 2 years?”. Some items were adapted for use in the UK, replacing some words which are specific to America, for example using the term “SIPP” for a self-managed retirement account. McDonald’s Omegas were 0.88 (credit card), 0.71 (investment), 0.55 (loan), 0.65 (insurance), and 0.62 (financial advice). The reliability of the 22-item total was 0.80. The final component of financial literacy, financial time preference, was measured with 7 questions, each with 5 options (“Strongly Disagree” to “Strongly Agree”), e.g. “Money is there to be spent (reversed)”. The Coefficient Omega of time preference in our sample was 0.88. We validated the structure of these three overarching components of financial literacy (see Fig. 1).

Finally, we also recorded household income with 13 levels from “Less than GBP10,000” to “More than GBP150,000” coded 1 to 13. Education was scored with 7 levels: “No formal qualifications”, “Secondary education (e.g. GED/GCSE)”, “High school diploma/A-levels”, “Technical/community college”, “Undergraduate degree (BA/BSc/other)”, “Graduate degree (MA/MSc/MPhil/other)” and “Doctorate degree (PhD/other)”, coded from 1 to 7. This information was unavailable for 134 subjects.

3.2.1. Procedure

Participants were recruited through the Prolific Academic website; Prolific users would get a notification with a short introduction of this study from the system and be asked whether they want to join in or not. People who chose to join in this study would be redirected to our online survey which produced by Qualtrics. After being shown an Information Sheet, participants were offered a consent form. Only participants who choose to join the study voluntarily could proceed to the scales. Items and scales were presented online in the order reported above. After

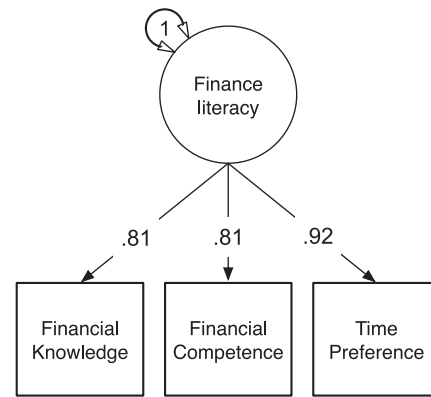


Fig. 1. Measurement model of financial literacy and manifest measures of financial knowledge, financial competence, and time preference.

participants completed the study, a debriefing sheet was shown explaining the details and purpose of this study, and they were returned to prolific academic to verify their participation and receive payment.

4. Results

Descriptive statistics and correlations of the main variables in study 1 are shown in Table 1. Before proceeding to test our hypotheses, we wished to establish that the broad set of Allgood and Walstad (2016) and Inderst et al. (2013) scales used here to assess financial literacy formed a factor which we could use for subsequent analyses. To do this the 35 items were scored and summed into their respective financial knowledge, financial competence, and financial time preference scales. A maximum likelihood confirmatory factor model was conducted in R using the umxRAM function of the umx package (Bates, Maes, & Neale, 2019). This indicated that, as predicted, Financial Knowledge, Financial Competence, and Financial Time Preference were well accounted for by a single latent Financial Literacy factor (see Fig. 1). Given the high loadings of all three subscales, we used the sum-score as our indicator of total financial literacy in subsequent analyses.

Our first hypothesis was that cognitive ability would be positively associated with economic knowledge. This was tested using a linear model with total cognitive ability score as the independent variable, and economic knowledge as the dependent variable, controlling for age, gender, household income, and education level. This prediction was fully supported by our data. As shown in Fig. 2, cognitive ability was significantly associated with economic knowledge in the predicted direction ($t(516) = 13.94, p < .001$) with $\beta = 0.51$ (CI95% [0.44, 0.58]). These results, then, supported the prediction that brighter people have better understanding of economic mechanisms, and this relationship was not accounted for by education.

Hypothesis two, that cognitive ability would be positively associated with financial literacy was tested using regression, with total cognitive ability as the independent variable and total financial literacy score as the dependent variable, controlling for age, gender, household income, and education level. As predicted, cognitive ability was significantly related to financial literacy ($t(335) = 4.18, p < .001$) though with an effect size smaller than that found for economic knowledge ($\beta = 0.19$, CI95% [0.10, 0.29]).

As shown in Table 2, at the sub-scale level for financial literacy, the correlation of cognitive ability varied widely, with strong links to financial knowledge subscale, weaker associations with the investment literacy component in financial competence subscale and time preference subscale, and smaller links to other variables, e.g. paying off a credit card on time. These results support the predicted positive association of cognitive ability with general financial literacy, but leave open the possibility of varying associations within the financial literacy

Table 1
Descriptive statistics and inter-correlations of variables in Study 1.

	Mean (SD)	1	2	3	4	5	6	7	8	9	10	11
1. Cognitive Ability	0.00 (1.13)	–										
2. Verbal Reasoning	10.20 (2.92)	0.83***	–									
3. Letter and Number	4.02 (2.82)	0.86***	0.55***	–								
4. Matrix Reasoning	4.64 (2.85)	0.80***	0.51***	0.53***	–							
5. Economic Knowledge	28.72 (6.19)	0.55***	0.54***	0.43***	0.39***	–						
6. Financial Knowledge	0.00 (1.24)	0.40***	0.37***	0.33***	0.28***	0.43***	–					
7. Financial Competence	0.00 (1.08)	0.07	0.09*	0.06	0.02	0.17***	0.28***	–				
8. Time Preference	0.00 (1.08)	0.19***	0.15*	0.16**	0.15*	0.21***	0.33***	0.21***	–			
9. Age	–	0.14***	0.10*	0.17***	0.09*	0.28***	0.21***	0.32***	0.13**	–		
10. Gender	–	–0.11**	–0.06	–0.10*	–0.11**	–0.11**	–0.13**	0.09*	–0.01	0.05	–	
11. Household income	–	0.09*	0.18***	0.01	0.05	0.17***	0.24***	0.26***	0.16**	–0.01	0.03	–
12. Education Level	–	0.25***	0.30***	0.19***	0.15***	0.18***	0.28***	0.13**	0.13*	–0.07	–0.05	0.22***

Note. Cognitive Ability was the factor score of Verbal Reasoning, Letter and Number, and Matrix Reasoning, the range of scores was from –2.65 to 2.55. The range of scores for Verbal Reasoning was from 0 to 16; the range of scores for Letter and Number was 0 to 9; the range of scores for Matrix Reasoning was 0 to 11; the range of scores for Economic Knowledge was 0 to 40; the range of the factor score of Financial Knowledge was –3.89 to 3.26; the range of the factor score of Financial Competence was –1.07 to 3.09; the range of the factor score of Time Preference was –4.06 to 1.98. *** = $p < .001$, ** ≤ 0.01 , * ≤ 0.05 .

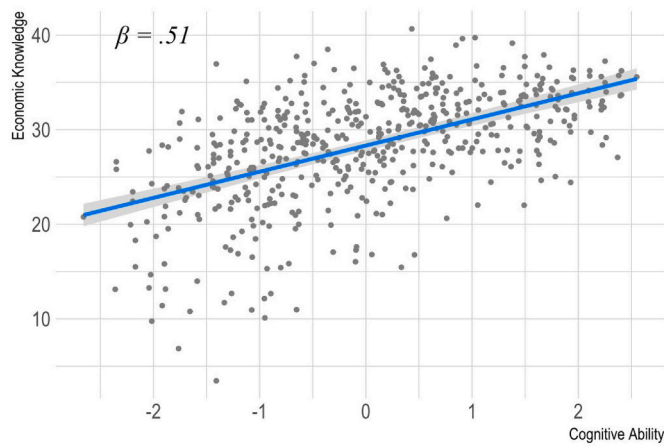


Fig. 2. Association of economic knowledge with cognitive ability (Study 1). Note: Graph shows partial residuals between Economic Knowledge and Cognitive Ability conditional on age, gender, household income and education level. Plots produced using the R package “visreg”, see also Breheny and Burchett (2017).

construct.

We next tested the predicted association of economic knowledge with financial literacy. This was tested using regression with economic knowledge as the dependent variable, and financial literacy as the independent variable, controlling for age, gender, household income, and education level. As predicted, economic knowledge was significantly associated with financial literacy in the predicted direction ($t(335) = 4.28, p < .001$) with beta value of 0.25 (CI95% [0.14, 0.37]).

Structural equation modelling was used to further analyse the relationship between cognitive ability, economic knowledge, financial

Table 2

Raw correlations among cognitive ability, and subscales of financial literacy (financial knowledge subscale, the five components of financial competence subscale, and time preference subscale) in Study 1.

	1	2	3	4	5	6	7
1. Cognitive Ability	–						
2. Financial Knowledge	0.40***	–					
3. Credit Card	–0.03	–0.03	–				
4. Investment	0.13***	0.43***	0.19***	–			
5. Loan	0.05	0.22***	0.40***	0.39***	–		
6. Insurance	0.08*	0.21***	0.49***	0.42***	0.69***	–	
7. Financial Advice	0.04	0.12*	0.34***	0.38***	0.56***	0.54***	–
8. Time Preference	0.19***	0.33***	–0.37***	0.31***	0.21***	0.17***	0.16***

Note. The scores of Credit Card, Investment, Loan, Insurance and Financial Advice were the item sum of each scale. *** = $p < .001$, ** ≤ 0.01 , * ≤ 0.05 .

literacy, and education. This structural model had an acceptable fit ($\chi^2(6) = 25.30, p < .001$), RMSEA = 0.07, CFI = 0.978, TLI = 0.946), with almost all fit statistics of the model meeting recommended cut-off criteria (Hair, Black, Babin, & Anderson, 2010; Schreiber, Nora, Stage, Barlow, & King, 2006). As shown in Fig. 3, this model showed general cognitive ability links to economic knowledge, financial literacy and education, the beta of each path was 0.64 (CI95% [0.58, 0.71]), 0.15 (CI95% [0.01, 0.30]) and 0.31 (CI95% [0.22, 0.40]), respectively. Furthermore, although financial literacy and education had a significant association (beta = 0.19 CI95% [0.09, 0.29]), the relationship between economic knowledge and education was not significant (beta = –0.02 CI95% [–0.10, 0.06]). These results indicated again that bright people have better knowledge on economic, and this relationship is not mediated by education level.

5. Discussion

Study 1 showed that cognitive ability is positively associated with both economic knowledge and financial literacy. Jointly, cognitive ability accounted for 30% of variance in economic knowledge and 9% of variance in financial literacy. Within these major links, three additional findings are worthy of note. First, a better understanding of economics was related to multiple domains of cognitive ability: reasoning skills, working memory and spatial abilities, supporting the idea that links of cognitive ability to greater awareness of how the economy works are not restricted to numerical skills. Similarly, financial literacy was associated with all domains of cognitive ability – again indicating that improved financial literacy is not restricted to specific skills within cognitive ability. Second, this study indicated that economic knowledge and financial literacy are two independent concepts although they were positively associated with each other. Plausibly, the general capacity for knowledge, understanding, and reasoning involved in general ability becoming crystalized in increased economic knowledge and financial

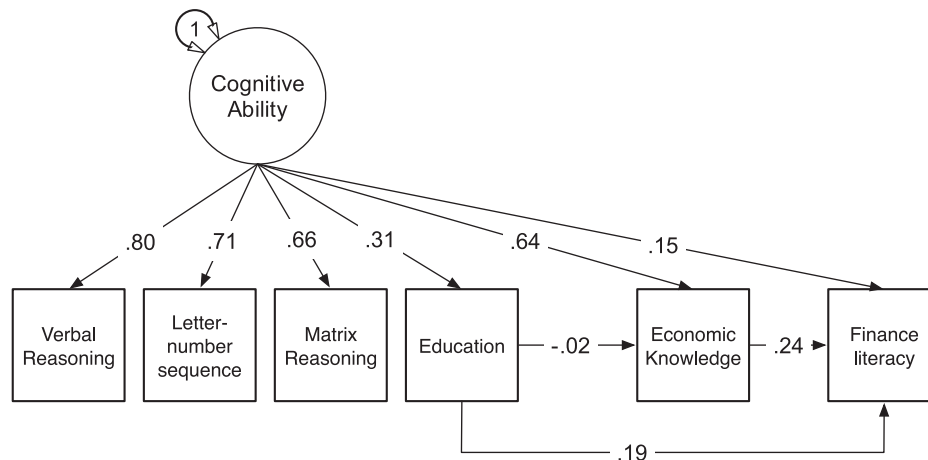


Fig. 3. Structural equation/path models of main variables in Study 1. Fit statistics: CFI = 0.978, TLI = 0.946, RMSEA = 0.070, $\chi^2(6) = 25.30$, $p < .001$.

literacy. Third, although cognitive ability and education level were correlated, the positive relationship between cognitive ability and economic knowledge remained virtually unchanged when education level was controlled. This finding suggests that better economic knowledge is not merely a proxy of high education level. We explore this more detail in study 2.

Having demonstrated the relationships between cognitive ability, economic knowledge and financial literacy, we set out to test the replicability of these findings in a second, independent and pre-registered study, presented next.

6. Study 2

Study 1 confirmed the role of cognitive ability in understanding economic mechanisms and finance. In study 2, we set out to replicate each finding from Study 1 with a different cognitive ability measure, verifying whether the relationships between these variables are stable or not. We also wished to measure and control two potential confounds simultaneously, namely specific training encountered in formal courses, and increased exposure to education.

An important question we wished to address was to further delimit the role of education by testing specific training in economics. Surprisingly, the literature in this area suggests only very weak effects of economic training on economic knowledge (Walstad & Allgood, 1999). If general ability is related to economic knowledge after controlling for these exposure and training factors, the association would be of even more interest. Therefore, we replicated our findings in Study 1, testing our four main hypotheses that 1) cognitive ability is positively correlated with economic knowledge, 2) cognitive ability is positively correlated with financial literacy, and 3) economic knowledge is positively correlated with financial literacy, controlling for age, gender, household income, education level and economic training. Predictions and sample size were pre-registered on [AsPredicted.org](https://aspredicted.org).

7. Method

7.1. Subjects

A total of 700 participants were recruited using Prolific Academic, an online platform for recruiting subjects for research (350 females, mean age 41.10 years, minimal age = 20, maximal age = 75, SD = 13.06). We pre-registered a criterion that subjects who completed the questionnaire <3 min would be excluded. No subjects met this criterion. The racial mix of the sample was representative of the UK, with participants identifying as White ($n = 647$; 92.4%), Asian ($n = 22$; 3.1%), Mixed ($n = 17$; 2.4%), Black ($n = 12$; 1.7%) and other ($n = 2$; 0.3%). The distribution of

household income of samples was close to general population, but the percentage of participants who attained a bachelor's or equivalent tertiary education degree was higher than general population in our sample. The study was approved by the Psychology Research Ethics Committee at the School of Philosophy, Psychology & Language Sciences in the University of Edinburgh. All participants gave informed consent.

7.2. Measures and procedure

Cognitive ability was measured using three measures: (1) A sentence verification test linked to processing speed (Baddeley, 1968); (2) A paper folding task linked to spatial manipulation (Ekstrom, French, Harman, & Dermen, 1976); and (3) A vocabulary test (Warrington, McKenna, & Orpwood, 1998). Paper Folding included 10 questions each with 3 images showing the process of folding a square of paper before punching a hole in it. Participant's task was to pick the correct image from 5 options showing the result when the paper was unfolded. The Coefficient omega of Paper Folding Test was 0.79 in our sample. Sentence Verification used 32 True/False questions in which participants indicated the truth or falsity of sentences of the format "A: A is before B". The Coefficient omega of Sentence Verification was 0.91 in our sample. Finally in the 25 item Vocabulary Measure, participants viewed target words, and were required to select from two options words which the same meaning as the target. The Coefficient omega of Vocabulary Measure was 0.71 in our sample. The factor score of Paper Folding Test, Sentence Verification, and Vocabulary Measure were used as the total cognitive ability score in this study.

Economic knowledge and financial literacy were measured as in Study 1. The Coefficient omega of the Test of Economic Knowledge was 0.85 in our sample. The Coefficient omega of the financial knowledge subscale and the time preference subscale of financial literacy was 0.57 and 0.87, respectively. The Coefficient omega of each component in the financial competence subscale of financial literacy were 0.88 (credit card), 0.71 (investment), 0.44 (loan), 0.70 (insurance), and 0.66 (financial advice), and the reliability of all 22 items was 0.81. Formal training in economics was measured by asking "What is the highest level of formal economic course you have completed?" with options for different levels of economics training using the same 7 levels used in assessing overall education. Other demographic information (age, gender, household income and education level) was collected as in study 1.

The procedure duplicated that of Study 1: subjects consented online to participate in the study, and then completed items presented through Qualtrics, an online survey system. The order of scales was as the same as we presented in this section. Subjects were paid £2.80.

8. Results

The descriptive statistics and correlations of main variables in study 2 are shown in Table 3.

The first hypothesis – that cognitive ability and economic knowledge are strongly associated replicated. This prediction was tested using regression with cognitive ability as the independent variable, and economic knowledge as the dependent variable, controlling for age, gender, household income, education level and economic training. Supporting the prediction, cognitive ability was significantly associated with economic knowledge in the predicted direction ($t(691) = 10.36, p < .001$) with beta value of 0.33 (CI95% [0.26, 0.39]). These results, then, replicated our findings from Study 1, showing that brighter people have more understandings of economic mechanisms, and this relationship is not caused by education and economic training.

The second hypothesis, the positive association between cognitive ability and financial literacy replicated. This prediction was tested using regression, with total cognitive ability score as the independent variable, and the total financial literacy score as dependent variables, controlling for age, gender, household income, education level and economic training. As predicted, cognitive ability significantly related to financial literacy ($t(691) = 4.26, p < .001$) though with an effect size smaller than that found for economic knowledge ($\beta = 0.14, CI95\% [0.07, 0.20]$).

The association of economic knowledge and financial literacy also replicated. A regression of economic knowledge on financial literacy, controlling for age, gender, household income, education level, and economic training showed a significant association of economic knowledge with financial literacy in the predicted direction ($t(691) = 8.81, p < .001$; $\beta = 0.33, CI95\% [0.26, 0.41]$). The relationship between economic knowledge and financial knowledge thus closely replicated the findings in study 1.

Finally, we tested structural equation model with the relationship between cognitive ability, economic knowledge, financial literacy, education level and economic training level. This model had good fit ($\chi^2(7) = 13.98, p = .052$, RMSEA = 0.038, CFI = 0.993, TLI = 0.979 (Hair et al., 2010; Schreiber et al., 2006)). As shown in Fig. 4, effects of

cognitive ability on economic knowledge ($\beta = 0.76, CI95\% [0.65, 0.86]$) and education ($\beta = 0.34, CI95\% [0.24, 0.43]$) were significant. Although financial literacy had no relationship with education ($\beta = 0.06, CI95\% [-0.03, 0.14]$), it showed a significant association with economic training level ($\beta = 0.09, CI95\% [0.02, 0.17]$). By contrast, economic knowledge had no relationship with education ($\beta = 0.02, CI95\% [-0.10, 0.13]$) and economic train level ($\beta = 0.04, CI95\% [-0.05, 0.12]$). This result successfully replicated the finding in study 1, indicating again that the association between cognitive ability and economic knowledge was not caused by education or economic training.

9. General discussion

Study 2 successfully replicated all study 1 findings relating cognitive ability to economic knowledge and to financial literacy. Four major results emerged in this set of studies. First, controlling for multiple demographic variables, cognitive ability accounted for substantial variance in economic knowledge and in financial literacy. Second the association of cognitive ability with economic knowledge was largely unchanged when education level was controlled. Even controlling for economic training left the association largely undiminished. This suggests that the association of cognitive ability and economic knowledge is not an artifact of exposure to education or, perhaps even more surprisingly, even of specific training in economics. Though this is contrary to some intuitions regarding effects of teaching, it is in line with large studies testing intelligence, knowledge, and knowledge acquisition (Ree & Carretta, 2022). These show that intelligence is powerful predictor of knowledge and knowledge acquisition, but that knowledge itself is a poor predictor of knowledge acquisition. The findings, then, are in line with the idea that knowledge acquisition is strongly under the control of cognitive ability and with relatively weaker effects of teaching due to the strong influence of ability on knowledge acquisition (Ree & Carretta, 2022). Third, supporting importance of cognitive ability for financial wellbeing, we found that brighter people reported better management of investment, insurance, and careful spending. Finally, study 2 replicated the link between cognitive ability, economic knowledge, and financial

Table 3
Descriptive statistics and inter-correlations of variables in Study 2.

	Mean (SD)	1	2	3	4	5	6	7	8	9	10	11	12
1. Cognitive Ability	0.00 (1.21)	–											
2. Paper Folding	4.73 (2.37)	0.60***	–										
3. Sentence Verification	17.85 (6.48)	0.95***	0.39***	–									
4. Vocabulary Measure	19.31 (3.30)	0.48***	0.20***	0.31***	–								
5. Economic Knowledge	29.72 (5.89)	0.39***	0.27***	0.28***	0.57***	–							
6. Financial Knowledge	0.00 (1.20)	0.31***	0.20***	0.24***	0.36***	0.61***	–						
7. Financial Competence	0.00 (1.15)	0.05	0.06	0.02	0.12**	0.19***	0.33***	–					
8. Time Preference	0.00 (1.09)	0.10**	0.06	0.08*	–0.13***	0.24***	–0.33***	0.20***	–				
9. Age	–	–0.07	–0.20***	–0.12**	0.41***	0.30***	0.25***	0.25***	0.13***	–			
10. Gender	–	–0.10**	–0.07	–0.06	–0.18***	–0.31***	–0.36***	–0.10**	–0.11**	–0.16***	–		
11. Household income	–	0.16***	0.13***	0.15***	0.05	0.19***	0.27***	0.45***	0.12**	–0.08*	–0.06	–	
12. Education Level	–	0.23***	0.13***	0.20***	0.23***	0.29***	0.28***	0.11**	0.13***	–0.07	–0.11**	0.20***	–
13. Economic Training	–	0.07	0.06	0.07	0.02	0.09*	0.19***	0.10**	0.05	–0.14***	–0.06	0.16***	0.53***

Note. Cognitive Ability is the factor score of Paper Folding, Sentence Verification, and Vocabulary Measure, the range of scores was from –2.78 to 3.09. The range of scores for Paper Folding was from 0 to 10; the range of scores for Sentence Verification was 0 to 32; the range of scores for Vocabulary Measure was 0 to 25; the range of scores for Economic Knowledge was 0 to 40; the range of factor score of Financial Knowledge was –3.37 to 2.49; the range of factor score of Financial Competence was –1.74 to 2.84; the range of factor score of Time Preference was –2.25 to 2.69. *** = $p < .001$, ** ≤ 0.01 , * ≤ 0.05 .

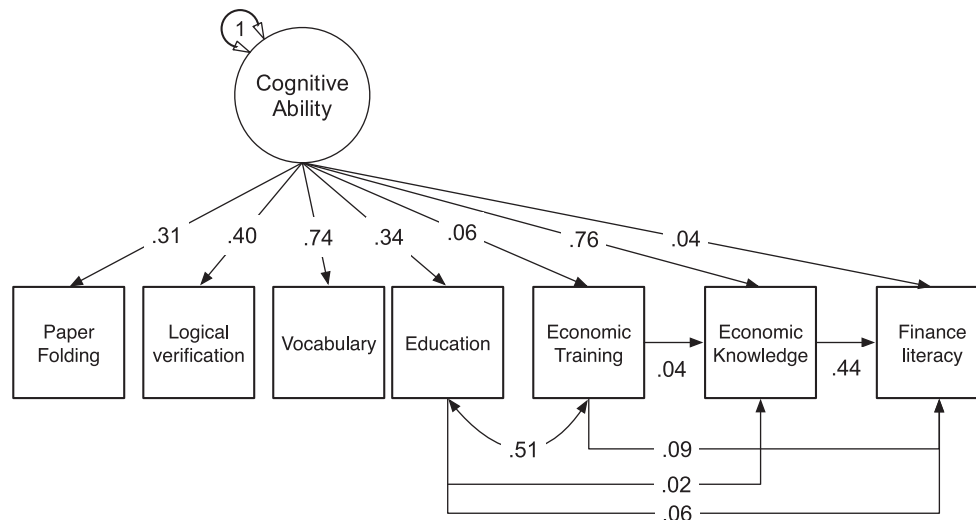


Fig. 4. Structural equation/path models of main variables in Study 2. Fit statistics for this model are as follows: CFI = 0.993, TLI = 0.979, RMSEA = 0.038, $\chi^2(7) = 13.98$, $p = .052$.

literacy. These robust positive associations of cognitive ability with economic knowledge and financial literacy are compatible with the possibility that improvements in general ability may cascade into valued improvements not only in economic knowledge but also in lifetime financial outcomes.

9.1. Future directions and limitations

We found that cognitive ability is associated with improved economic knowledge, even controlling for education and specific exposure to economics education. Economic knowledge thus joins the growing set of “mental toolkits” such as knowledge of scientific reasoning and analytic thinking (Cavojeová, Šrol, & Jurkovič, 2020; Ståhl & Van Prooijen, 2018) positively associated with cognitive ability. Identifying additional mental toolkits linked to cognitive ability is a valuable direction for future study. By contrast, the lack of association of formal education with knowledge and literacy suggests that intelligent people may actively seek out, learn, and abstract this economic knowledge as an aid to understanding the world and achieving their goals, even when, and independent of exposure to formal education. Capitalising on whatever these self-guided opportunities are would be of value. The finding that, despite economics being one of the most popular subjects in higher education (Brückner et al., 2015), economic training had only a tiny influence on economic knowledge, suggests that future research might focus on improving the efficacy of economic education. Also, since financial literacy was reliably associated with education and economic training, effective education investments leading to improved student outcomes could influence wellbeing via improved financial behaviours.

This research has limitations that should also be mentioned. The financial knowledge subscale of financial literacy proved less reliable than desirable. Other studies have found modest reliabilities for some of these scale, e.g. in the National Financial Capability Study Omega was under 0.7 (NFCS, 2018). More robust measure of financial knowledge may be possible: For instance including options which include additional choices, such as “not having life insurance but I have no dependants”. Testing could also usefully be expanded to include novel financial products, for instance cryptocurrency (Steinmetz, von Meduna, Ante, & Fiedler, 2021) and non-fungible tokens (Trautman, 2021). Given the trillions of dollars involved, volatility, legal frameworks, etc. association of these assets may differ in their association with ability. Another limitation is that we recruited only UK participants. Replicating these findings in different cultures with distinct norms, for instance, surrounding private ownership or lending money for interest, for

example, the concept of *Riba* (Siddiqi, 2004), our findings would be more robust. Future research could also use these findings to help unpack links of cognitive ability to cognate topics, such as economic attitudes.

To conclude, the present studies corroborated the associations between cognitive ability and multiple financial outcomes. The data provided evidence for substantial positive effects of cognitive ability on economic knowledge in addition to financial literacy. In addition, the studies highlighted surprising weak effects of (current) education and economics training on economic knowledge independent of ability. Economic knowledge and financial literacy are central topics in areas of socioeconomics, political policy, and economics, but the present results suggest a role for cognitive ability which is too seldom discussed. This research begins to fill this gap.

Funding

This research was supported by the PPLS PhD students Research Support Grants.

Declaration of Competing Interest

We declare that we have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.intell.2022.101667>.

References

- Agarwal, S., & Mazumder, B. (2013). Cognitive abilities and household financial decision making. *American Economic Journal: Applied Economics*, 5(1), 193–207.
- Allgood, S., & Walstad, W. B. (2016). The effects of perceived and actual financial literacy on financial behaviors. *Economic Inquiry*, 54(1), 675–697.
- Anderson, A., Baker, F., & Robinson, D. T. (2017). Precautionary savings, retirement planning and misperceptions of financial literacy. *Journal of Financial Economics*, 126(2), 383–398.
- Atkinson, A., & Messy, F.-A. (2012). *Measuring financial literacy: Results of the OECD/ international network on financial education (INFE) pilot study*.
- Baddeley, A. D. (1968). A 3 min reasoning test based on grammatical transformation. *Psychonomic Science*, 10, 341–342.
- Bates, T. C., Maes, H., & Neale, M. C. (2019). umx: Twin and path-based structural equation modeling in R. *Twin Research and Human Genetics*, 22(1), 27–41.

- Breheny, P., & Burchett, W. (2017). Visualization of regression models using visreg. *The R Journal*, 9(2), 56.
- Brückner, S., Förster, M., Zlatkin-Troitschanskaia, O., Happ, R., Walstad, W. B., Yamaoka, M., & Asano, T. (2015). Gender effects in assessment of economic knowledge and understanding: Differences among undergraduate business and economics students in Germany, Japan, and the United States. *Peabody Journal of Education*, 90(4), 503–518.
- Čavojová, V., Šrol, J., & Jurković, M. (2020). Why should we try to think like scientists? Scientific reasoning and susceptibility to epistemically suspect beliefs and cognitive biases. *Applied Cognitive Psychology*, 34(1), 85–95.
- Ceci, S. J., & Williams, W. M. (1997). Schooling, intelligence, and income. *American Psychologist*, 52(10), 1051.
- Cowen, T. (2007, August 9). Inside the mind of the inner economist/interviewer: N. Gillespie. Reason. <https://reason.com/2007/08/10/inside-the-mind-of-the-inner-e/>.
- D'Acunto, F., Hoang, D., Paloviita, M., & Weber, M. (2019). IQ, expectations, and choice. *NBER working paper series no. 25496*. National Bureau of Economic Research. Retrieved from <http://www.nber.org/papers/w25496>.
- Delavande, A., Rohwedder, S., & Willis, R. J. (2008). Preparation for retirement, financial literacy and cognitive resources. In *Michigan retirement research center research paper(2008–190)*.
- Ekstrom, R. B., French, J. W., Harman, H. H., & Dermen, D. (1976). *Kit of factor-referenced cognitive tests*. Princeton, New Jersey: ETS Research and Development.
- Finke, M. S., Howe, J. S., & Huston, S. J. (2017). Old age and the decline in financial literacy. *Management Science*, 63(1), 213–230.
- Gaurav, S., & Singh, A. (2012). An inquiry into the financial literacy and cognitive ability of farmers: Evidence from rural India. *Oxford Development Studies*, 40(3), 358–380.
- Gleason, J., & Van Scyoc, L. J. (1995). A report on the economic literacy of adults. *The Journal of Economic Education*, 26(3), 203–210.
- Grinblatt, M., Ikaheimo, S., Keloharju, M., & Knüpfer, S. (2016). IQ and mutual fund choice. *Management Science*, 62(4), 924–944.
- Grinblatt, M., Keloharju, M., & Linnainmaa, J. (2011). IQ and stock market participation. *The Journal of Finance*, 66(6), 2121–2164.
- Grinblatt, M., Keloharju, M., & Linnainmaa, J. T. (2012). IQ, trading behavior, and performance. *Journal of Financial Economics*, 104(2), 339–362.
- Hair, J. F., Black, W. C., Babin, B. J., & Anderson, R. E. (2010). *Multivariate data analysis* (7th ed.). Pearson.
- Herd, P., Holden, K., & Su, Y. T. (2012). The links between early-life cognition and schooling and late-life financial knowledge. *Journal of Consumer Affairs*, 46(3), 411–435.
- Hsu, J. W. (2016). Aging and strategic learning: The impact of spousal incentives on financial literacy. *Journal of Human Resources*, 51(4), 1036–1067.
- Hung, A., Parker, A. M., & Yoong, J. (2009). *Defining and measuring financial literacy*. Inderst, G., Della Croce, R., Stewart, F., Yermo, J., Atkinson, A., Messy, F.-A., ... Caldecott, B. (2013). *OECD working papers on finance, insurance and private pensions*. OECD.
- Jedinger, A., & Burger, A. M. (2021). Do smarter people have more conservative economic attitudes? Assessing the relationship between cognitive ability and economic ideology. *Personality and Social Psychology Bulletin*. <https://doi.org/10.1177/01461672211046808>
- Kramer, M. (2012). Financial literacy, cognitive ability and financial advice-seeking. SSRN. <https://doi.org/10.2139/ssrn.2081795> (June 11, 2012) <https://ssrn.com/abstract=2081795>.
- Legg, S., & Hutter, M. (2007). A collection of definitions of intelligence. *Frontiers in Artificial Intelligence and Applications*, 157, 17.
- Lewis, G. J., & Bates, T. C. (2018). Higher levels of childhood intelligence predict increased support for economic conservatism in adulthood. *Intelligence*, 70, 36–41. <https://doi.org/10.1016/j.intell.2018.07.006>
- Li, Y., Baldassi, M., Johnson, E. J., & Weber, E. U. (2013). Complementary cognitive capabilities, economic decision making, and aging. *Psychology and Aging*, 28(3), 595.
- Li, Y., Gao, J., Enkavi, A. Z., Zaval, L., Weber, E. U., & Johnson, E. J. (2015). Sound credit scores and financial decisions despite cognitive aging. *Proceedings of the National Academy of Sciences*, 112(1), 65–69.
- Lusardi, A., Mitchell, O. S., & Curto, V. (2010). Financial literacy among the young. *Journal of Consumer Affairs*, 44(2), 358–380.
- Mankiw, N. G., & Taylor, M. P. (2020). *Economics* (5th ed.). Andover: Cengage Learning.
- Muñoz-Murillo, M., Álvarez-Franco, P. B., & Restrepo-Tobón, D. A. (2020). The role of cognitive abilities on financial literacy: New experimental evidence. *Journal of Behavioral and Experimental Economics*, 84, Article 101482.
- NFCS. (2018). The national financial capability study state-by-state survey [data file]. Retrieved from: <https://www.usfinancialcapability.org/downloads.php>.
- Noctor, M., Stoney, S., & Stradling, R. (1992). *Financial literacy: A discussion of concepts and competences of financial literacy and opportunities for its introduction into young people's learning*. National Foundation for Educational Research.
- Ree, M. J., & Carretta, T. R. (2022). Thirty years of research on general and specific abilities: Still not much more than g. *Intelligence*, 91. <https://doi.org/10.1016/j.intell.2021.101617>
- Revelle, W., Condon, D., Doeblér, P., Holling, H., Rust, J., Stillwell, D., & Loe, A. (2014). The international cognitive ability resource team. Retrieved from <https://icar-project.com/>.
- Ritchie, S. J., Bates, T. C., & Deary, I. J. (2015). Is education associated with improvements in general cognitive ability, or in specific skills? *Developmental Psychology*, 51(5), 573–582. <https://doi.org/10.1037/a0038981>
- Schreiber, J. B., Nora, A., Stage, F. K., Barlow, E. A., & King, J. (2006). Reporting structural equation modeling and confirmatory factor analysis results: A review. *The Journal of Educational Research*, 99(6), 323–338.
- Siddiqi, M. N. (2004). *Riba, bank interest and the rationale of its prohibition*. Islamic Research and Training Institute Jeddah.
- Skagerlund, K., Lind, T., Strömbäck, C., Tinghög, G., & Västfjäll, D. (2018). Financial literacy and the role of numeracy—how individuals' attitude and affinity with numbers influence financial literacy. *Journal of Behavioral and Experimental Economics*, 74, 18–25.
- Sloman, J., Guest, J., & Garratt, D. (2018). In J. Sloman, J. Guest, & D. Garrett (Eds.), *Economics* (Tenth ed.). Upper Saddle River: Pearson.
- Stahl, T., & Van Prooijen, J.-W. (2018). Epistemic rationality: Skepticism toward unfounded beliefs requires sufficient cognitive ability and motivation to be rational. *Personality and Individual Differences*, 122, 155–163.
- Steinmetz, F., von Meduna, M., Ante, L., & Fiedler, I. (2021). Ownership, uses and perceptions of cryptocurrency: Results from a population survey. *Technological Forecasting and Social Change*, 173, Article 121073.
- Stella, G. P., Filotto, U., & Cervellati, E. M. (2020). A proposal for a new financial literacy questionnaire. *International Journal of Business and Management*, 15(2).
- Strenze, T. (2007). Intelligence and socioeconomic success: A meta-analytic review of longitudinal research. *Intelligence*, 35(5), 401–426.
- Trautman, L. J. (2021). *Virtual art and non-fungible tokens*. Available at SSRN 3814087.
- U.S. Financial Literacy & Education Commission. (2006). *Taking ownership of the future: The national strategy for financial literacy*. Washington, DC: Author.
- Wagner, J., & Walstad, W. B. (2019). The effects of financial education on short-term and long-term financial behaviors. *Journal of Consumer Affairs*, 53(1), 234–259.
- Walstad, W. B., & Allgood, S. (1999). What do college seniors know about economics? *American Economic Review*, 89(2), 350–354.
- Walstad, W. B., & Soper, J. C. (2010). *Test of economic knowledge*. New York: Examiner's Manual.
- Warrington, E. K., McKenna, P., & Orpwood, L. (1998). Single word comprehension: A concrete and abstract word synonym test. *Neuropsychological Rehabilitation*, 8(2), 143–154. <https://doi.org/10.1080/713755564>
- Wobker, I., Lehmann-Waffenschmidt, M., Kenning, P., & Gigerenzer, G. (2012). What do people know about the economy? A test of minimal economic knowledge in Germany. In *A test of minimal economic knowledge in Germany (October 1, 2012)*.